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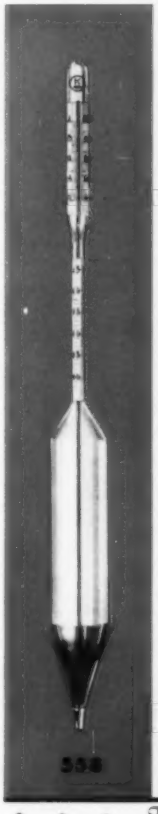

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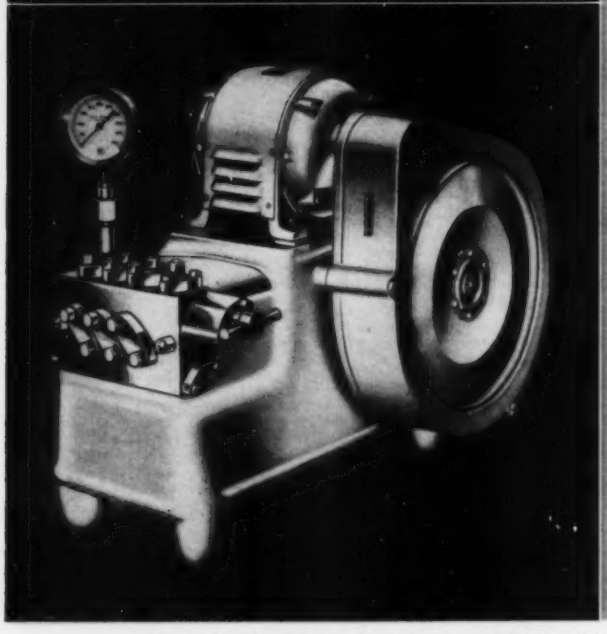

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JOURNAL OF DAIRY SCIENCE

VOLUME XXII NOVEMBER, 1939 NUMBER 11

IMPROVEMENT IN THE VISCOSITY OF PASTEURIZED CREAM THROUGH SUBSEQUENT HEAT TREATMENT

HILDA F. WIESE, J. H. NAIR AND R. S. FLEMING

The Borden Company Research Laboratory, Syracuse, N. Y.

A commercial process of alternately warming and cooling pasteurized cream for the purpose of increasing its viscosity was first described by Hening and Dahlberg in 1932 (1). Since then, one French, (2) one German (3) and three United States Patents (3, 4, 5) have been granted on various features of the process. With the exception of the Nair and Mook patent (U. S. 5) each of the other patents is concerned principally with the production of an increase in the viscosity of cream after pasteurization. The Nair and Mook patent specifies optimum conditions for obtaining "maximum improvement in the desired characteristics" which include "viscosity, whipping quality, serum separation, elimination of plug, cream line and proper control of bacterial growth." The objective of all of these published studies, however, has been the control of processing conditions to bring about a desired specific effect in the milk or cream.

Although it had been noted in the investigative work leading to the U. S. patent by Nair and Mook that all creams did not respond alike to a specific warming and cooling treatment, no data were available to determine which of the constituents of the milk or cream was responsible for these variable effects. The study reported in this paper was undertaken for the purpose of ascertaining which of the cream constituents was involved in the process.

For simplicity's sake, the described process of alternately warming and cooling pasteurized cream to improve its viscosity and other properties has been referred to in the Borden Laboratories as the "rebodying" process. The term "rebody" therefore, will be used throughout this paper to designate that process.

In undertaking the study, three major questions presented themselves; 1. was the fat phase or the aqueous phase of cream more important in the rebodying process, 2. was the composition or source of the butterfat a factor in the process, and 3. which of the plasma constituents of cream were helpful or injurious to the process.

The simplest method of studying each factor appeared to be an investi-

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gation of the effect of the rebodying process on artificial creams made by dispersing melted butterfat in an aqueous phase containing various milk solids. In making the dispersions, butterfat from four localities in the United States was used. All of the constituents of the aqueous phase, however, were derived from milk or cream produced in central New York.

The data reported in this paper do not include all of the results with each artificial cream but are representative of three or more experiments with each kind of artificial cream.

EXPERIMENTAL PROCEDURE

The dispersing materials for the artificial creams were prepared as follows:

Sweet Rennet Whey. Sweet rennet whey was prepared in an experimental laboratory water-jacketed vat by adding 50 ml. of a 1:50 solution of rennet to two gallons of pasteurized skim milk warmed to 95° F. The curd set in about an hour, was cut with cheese knives and the whey heated to 130° F. The clear whey was siphoned off, cooled and half of it concentrated under vacuum. The concentrate was adjusted to 8.5–9.0 per cent solids before being used. The remaining half of the whey was dialyzed in cellophane bags against running tap water for 18 hours, concentrated under vacuum and diluted back to 9 per cent solids before being used.

Normal Sweet Cream Buttermilk. Normal sweet cream buttermilk was obtained by churning freshly pasteurized sweet cream. The buttermilk was passed through a DeLaval separator to remove unchurned fat and butter particles. It was used in normal concentration for making artificial creams. The total solids content was 8.5 per cent.

Washed Cream Buttermilk. In preparing washed cream and washed cream buttermilk, ten gallons of freshly separated heavy cream were diluted with twenty gallons of tap water at 105° F. in a thirty-gallon Cherry-Burrell spray vat, mixed, and separated in a DeLaval separator. Six gallons of cream were recovered. This was diluted again to thirty gallons with tap water at 105° F., mixed, and reseparated. The fat content of the cream washed in this way was 64–66 per cent. Although the above treatment was considerably less than the number of washings applied previously in studies on the isolation and composition of the material adsorbed on the surface of fat globules in cream, the object of the present experiment was not to wash away all of the materials present on the fat surfaces with the exception of those most closely adsorbed, but only to remove the major part of the plasma solids-not-fat in the cream. Rimpila and Palmer (6) have shown that the greatest decrease in phosphorus and proteins in cream occurs after the first washing.

The washed cream was pasteurized in the spray vat at 145° F. for thirty minutes, cooled to 50° F., churned, and the buttermilk and first butter washing recovered. These were passed through a DeLaval separator to remove

fat and butter particles and the separated buttermilk concentrated in vacuum. The washed cream buttermilk used for making the artificial creams contained 2 per cent of solids.

Artificial Creams. In preparing the artificial creams, the butterfat was obtained by melting sweet cream butter and decanting the practically clear butter-oil. Sufficient melted butterfat to give a 35 per cent cream was added to the aqueous emulsifying material, the mixture warmed to 105° F., and passed through a small viscolizer at 200 pounds three successive times. The viscolizer used was a No. 0 Union Steam pump machine equipped with a Duo-Visco valve having a No. 3 breaker ring. When not too heavy, the cream was cooled over a small surface cooler; otherwise it was cooled by setting the container in running tap water.

A microscopic examination was made of each cream to insure that it was very nearly like normal cream in degree of fat dispersion before the rebodying process was applied.

Three or more of each of the following emulsions were prepared:

Minnesota butterfat in New York normal fluid skim milk.
Minnesota butterfat in New York reliquefied skim powder.
Minnesota butterfat in New York condensed sweet rennet whey.
Minnesota butterfat in New York condensed dialyzed rennet whey.
Minnesota butterfat in New York normal sweet cream buttermilk.
Minnesota butterfat in New York condensed washed cream buttermilk.
New York butterfat in New York condensed washed cream buttermilk.
New York butterfat in New York normal sweet cream buttermilk.
New York butterfat in New York condensed dialyzed rennet whey.
Michigan butterfat in New York condensed washed cream buttermilk.
Texas butterfat in New York washed cream buttermilk.

It was possible to prepare a uniform 35 per cent cream in every case. However, some of the creams were thicker than others and not all of them were stabile after pasteurization, *i.e.*, the emulsion either broke during pasteurization or the cream took on a curdled appearance. In no case was the acidity of the cream greater than 0.13 per cent.

All of the creams were pasteurized and rebodied in a small laboratory experimental vat under the same experimental conditions as to rate and temperature of heating and cooling and degree of agitation. Two samples could be treated at the same time under identical conditions. Pasteurization was carried out by holding for 30 minutes, followed by surface cooling to 45° F. The rebodying process consisted of immediately warming the pasteurized samples to 86° F. in 20–25 minutes, vat cooling from 86° F. to 65° F. in 12–15 minutes, followed by surface cooling to 45° F. After 24 hours storage at 40° F., the viscosity of the creams was measured in seconds flow time at 60° F. with the Borden Body Flow Meter (7).

Characteristics of the creams and typical effects of the rebodying process are given in Table 1.

TABLE 1

Effect of different plasma ingredients on the rebodying process of artificial creams

Source of butterfat	Stabilizing material from New York milk and cream	Acidity of artificial cream	Viscosity flowtime		Increase in viscosity
			After pastzn.	After rebodying	
		Per cent	*Seconds*	*Seconds*	*Per cent*
Minnesota	Normal fluid skim	0.12	206.0	201.2	None
"	Reliquefied skim powder (Low percentage of soluble lactalbumin)	0.13	710.0	679.0	None
"	Condensed sweet rennet whey (Lacking casein, but high in lactalbumin, lactose and milk salts)	0.11	62.0	57.5	None
"	Condensed dialyzed rennet whey (High percentage of lactalbumin, low percentage of lactose and milk salts and lacking casein)	0.11	87.7	76.7	None
"	Normal sweet cream buttermilk (Fat membrane material plus constituents of normal fluid skim)	0.11	curdled during pasteurization		
"	Washed cream buttermilk (contains only fat membrane material)	0.09	85.6	319.8	273
New York	Washed cream buttermilk	0.05	70.0	186.8	167
" "	Normal sweet cream buttermilk	0.12	curdled during pasteurization		
" "	Condensed dialyzed rennet whey	0.10	111.5	Badly churned	
Michigan	Washed cream buttermilk	0.03	56.5	95.1	68
Texas	" " "	0.03	61.7	119.1	93

A study of the results of the rebodying process on the artificial creams reported in Table 1 shows definitely that none of the constituents of normal fluid skim milk are capable of stabilizing butterfat in such a way as to make a cream which would respond to the rebodying process. Increase in viscosity of the artificial creams resulted only when the butterfat was stabilized with the membrane material of normal milk fat globules. This was true regardless of the source of the butterfat. However, it was found that the emulsions prepared with Michigan and Texas butterfat in washed cream buttermilk were much less stable than those prepared with New York or Minnesota butterfat. In fact, two of the three emulsions prepared in the former cases churned so badly during the rebodying process that viscosity measurements could not be made. In the creams prepared with Michigan and Texas butterfat which are reported in Table 1 the percentage increase

in viscosity after rebodying is also less than for the Minnesota and New York butterfat creams. This would indicate that the composition of the butterfat is a factor in the rebodying process. At least, it is a factor in the stabilization of the emulsions.

Failure to prepare 35 per cent butterfat emulsions in normal sweet cream buttermilk which were stable enough to undergo the rebodying process, may have been due to the low percentage of the fat globule membrane material. The normal buttermilk used in normal concentration contained a relatively small percentage of "membrane" material, whereas the washed cream buttermilk, containing 2 per cent of solids, was composed entirely of fat "membrane" material. When the above experiment with normal sweet cream buttermilk was repeated using 20 per cent of butterfat, more stable emulsions resulted and the creams had a slight response to rebodying (an increase of 18 seconds in the rebodied cream).

Addition of Skim Milk Solids to Washed Cream

Results of the effect of rebodying normal 35 per cent central New York cream before and after the removal of most of the solids-not-fat of the cream, showed that washed cream still responded well to the rebodying process. In order to check again the specific effect of the solids-not-fat in normal cream, skim milk solids and concentrated dialyzed rennet whey were added to washed cream before pasteurization.

Freshly separated heavy raw cream was washed twice in a spray vat as previously described. When the washed cream, containing 66 per cent butterfat, was reduced to 35 per cent butterfat with either reliquefied skim milk powder or condensed dialyzed rennet whey, then pasteurized and rebodied, the viscosity of the rebodied cream was greater than that of the washed cream itself. The viscosities of the original cream, the washed cream, and the washed cream with added solids after pasteurization and after rebodying are shown in Table 2.

TABLE 2

Effect on rebodying of adding plasma or serum solids to washed cream

	Viscosity flowtime		Increase in viscosity
	After pasteurization	After rebodying	
	seconds	*seconds*	*per cent*
Normal cream	114.4	375.5	228
Washed cream	56.7	159.2	180
Washed cream and reliquefied skim milk powder	80.3	252.9	214
Washed cream and dialyzed whey	66.4	257.5	287

Although no response to the rebodying process was brought about when one or more of the constituents of the aqueous phase of milk was used to

stabilize the butterfat in the artificial creams, the presence of these constituents in the aqueous phase of normal cream appears to play a part in the amount a cream responds to the rebodying process. This was evidenced by a lower percentage increase in the viscosity of rebodied washed cream as compared with unwashed cream and also by the greater percentage increase in the viscosity of rebodied washed cream to which skim milk solids had been added. Lactalbumin had a very definite effect.

Addition of Fat Membrane Material to Artificial Creams

Since the presence of the fat membrane material of normal cream played such an important part in the rebodying of artificial creams, as well as in washed cream, when used as the fat stabilizing material, concentrated solutions of washed cream buttermilk were added to other artificial creams in order to see whether beneficial effects could also be produced when the membrane material was present in the aqueous phase of the cream and not as the fat stabilizer. For this purpose, both New York and Michigan butterfat were dispersed in dialyzed sweet rennet whey to produce 40 per cent creams. These were standardized to 30 per cent butterfat with normal skim milk and concentrated washed cream buttermilk.

TABLE 3

Effect on rebodying of adding washed cream buttermilk solids to artificial cream stabilized with serum solids

	Viscosity flowtime	
	After pasteurization	After rebodying
	seconds	*seconds*
New York butterfat stabilized with serum solids, washed cream buttermilk added	44.6	48.5
Michigan butterfat stabilized with serum solids, washed cream buttermilk added	45.2	48.5

The artificial cream made with New York butterfat and sweet rennet whey, and standardized with skim milk, churned during the rebodying process. When Michigan butterfat was substituted for New York butterfat, the pasteurized artificial cream churned too badly to be subjected to rebodying. In the case of the two creams standardized with washed cream buttermilk, the addition of the fat membrane material in the aqueous phase of the cream, prevented the creams from churning during pasteurization but had practically no effect on the viscosity of the rebodied creams. The increases in viscosity after processing were negligible, as shown in Table 3.

SUMMARY AND CONCLUSIONS

1. The fat phase of normal cream plays the most important rôle in the cream rebodying process.

2. The fat membrane material of normal milk fat globules was found to be the most effective butterfat stabilizer for artificial creams and always resulted in a cream which would respond to the rebodying process.

3. Stabilization of butterfat with part or all of the constituents of normal skim milk did not yield artificial creams which would respond to rebodying, although the rebodying process as applied to other fat emulsions than cream has been patented (4). None of the emulsions prepared with other than the normal fat globule membrane material in these experiments responded to the process.

4. The constituents of the aqueous phase of normal cream exert a beneficial effect on the rebodying process but this effect is not noted except when the butterfat is stabilized by its normal membrane.

5. The composition of the butterfat appears to be a factor in the stability of cream subjected to the rebodying process.

REFERENCES

(1) HENING, J. C., AND DAHLBERG, A. C. A temperature treatment for increasing the viscosity of sweet cream. N. Y. State Agric. Exp. Sta. Tech. Bull., 197. 1932.

(2) CLEMMEDSON, B. A., AND ABRAHAMSSON, H. V. Process for improving the properties of milk and cream. Fr. Pat. 756,135. 1933.

(3) BERGMAN, T. V., AND SVEDBERG, H. A. Method of treating cream for increasing the viscosity thereof. U. S. Pat. 1,944,541. 1934. Ger. Pat. 613,277. 1935.

(4) HUNTER, O. W. Process for improving the viscosity of certain fatty liquids. U. S. Pat. 2,076,372. 1937.

(5) NAIR, J. H., AND MOOK, D. E. Treatment of milk products. U. S. Pat. 2,092,325. 1937.

(6) RIMPILA, C. E., AND PALMER, L. S. Substances adsorbed on the fat globules in cream and their relation to churning. IV. Factors influencing the composition of the adsorption "Membrane." J. DAIRY SC., 18: 827. 1935.

(7) NAIR, J. H., AND MOOK, D. E. Viscosity studies of fluid cream. J. DAIRY SC. 16: 1. 1933.

THE FLAVOR OF MILK AS AFFECTED BY SEASON, AGE, AND THE LEVEL OF FEEDING DAIRY COWS

J. C. HENING AND A. C. DAHLBERG

New York Agricultural Experiment Station, Geneva, N. Y.

An investigation with the station Jersey herd on the relation of input to output in milk production, in cooperation with the United States Department of Agriculture, afforded an excellent opportunity to study the effect of different levels of feeding upon milk flavors.

The object of the cooperative experiment was to determine the rate and method of feeding which is most profitable under different price conditions. The cows selected were divided into six comparable groups. The control group was fed at the Morrison Standard level. The other groups were fed at levels of 20 and 10 per cents below standard and 10, 20 and 30 per cents above standard. The roughage consisted of alfalfa hay (15 pounds daily per 1000 pounds body weight), corn silage (20 pounds daily), and mangels (15 pounds daily) and in the summer green cut alfalfa and green cut soy beans. The feeding of green cut legumes was started May 24th and discontinued September 27th. A good grain mixture of about 18.5 per cent crude protein was fed.

At the beginning of the experiment there were 6 cows on the −20 level, 3 cows on −10, +10 and +20 levels, and 6 cows on the +30 level. Before the first year of the experiment was completed some of the cows were sold from the herd due to causes not resulting from the experiment.

The cows were machine milked three times a day and fed grain three times a day. Hay was fed twice a day and mangels and silage once a day. The feeds, of course, were all analyzed and the amounts fed were weighed and any feed not eaten was weighed back. The high producing Jerseys of the station herd could not always consume enough food to meet the requirements of the higher levels of feeding and in two cases were changed to lower levels. These changes were taken into consideration in comparing the flavor scores of the milk. However, some of the cows at the higher levels of feeding included in this experiment, even though they were fed to the limit of their capacity, were not meeting the requirements of the level of feeding.

The experimental cows in the spring, summer and fall were on an exercise plot which furnished no appreciable pasturage since it was necessary to weigh and analyze the green feed they received.

The judging of the flavor of the milk from the individual cows was continued for one year. The milk was judged at the start of the experiment at weekly intervals, then every two weeks and once a month for the last few

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months of the experiment. The changes in flavor were not rapid enough to indicate the necessity of scoring the milk from individual cows every week. The flavor of the milk from all of the cows in the Jersey herd was scored whether or not they were on the experiment.

The study of the flavors for a complete year also offered an opportunity to study the effect of seasonal variations on the development of oxidized flavor. Likewise, since six heifers freshened during the year the flavor of their milk could be compared with that of the rest of the herd.

The experimental procedure was similar to that previously used (1). Samples of approximately one quart of milk from each cow were taken at the noon milking. One pint bottle of each of these samples was pasteurized at a temperature of 143° F. to 145° F. for one-half hour in a water bath. After pasteurization half of each pint of hot milk was poured into half pint bottles containing sufficient copper sulphate solution to increase the copper content by 0.25 p.p.m. It was considered to be desirable to add copper to part of the milk to determine more accurately the degree of susceptibility of the milk from each cow to the production of oxidized flavors. The milk was all cooled in the bottles in an ice-water bath and stored at 35 to 40° F. The raw milk was judged for flavor by 2 or 3 members of the department* shortly after milking and the raw, pasteurized and pasteurized plus copper milks were judged the first, third, and fifth days after milking and pasteurization. The flavor scores made on the fifth day are not included since the results are similar to those of the third day.

RESULTS

The Effect of Various Feeding Levels

Table 1 gives the average scores of the raw milk from individual cows judged the first and third day after milking and the pasteurized milk and pasteurized milk plus 0.25 p.p.m. copper judged the first and third day after milking. The average flavor scores given in this table show that the different levels of feeding have no influence on the flavor of the milk. The average flavor scores of milk from cows on the higher levels of feeding appear in some cases to be a little higher but this difference is not great enough to be considered significant, since other factors would account for some difference. The flavor of the milk from some groups of cows picked in this way would tend to be somewhat better than the flavor of the milk from other groups. The average flavor scores of the raw milk the first day after milking are practically the same for the – 20 and + 30 levels and the flavor scores for the pasteurized milk the first day after pasteurization are very much the same for each feeding level.

* The milk was scored for flavor by the authors and J. C. Marquardt working independently but some samples were not scored by the Junior author. The fresh raw samples were often judged by the Senior author alone.

TABLE 1

Average flavor scores for milk from cows of Jersey herd on various feeding levels from January 1937 through December 1937

Feeding level	No. of cows	Average flavor score of milk					
		Raw		Pasteurized		Past. plus 0.25 p.p.m. copper	
		1st day	3rd day	1st day	3rd day	1st day	3rd day
−20	6	22.2	20.9	21.6	19.8	20.4	16.5
−10	2	20.4	20.5	22.2	19.6	20.1	16.0
Standard	3	22.0	20.7	21.6	19.0	20.0	16.2
+10	3	22.4	20.6	21.7	19.6	18.5	15.4
+20	3	22.8	21.9	22.4	21.1	20.7	16.6
+30	4	22.5	21.4	22.2	20.4	20.8	15.9

Table 2 gives the percentage occurrence of oxidized flavor in the pasteurized milk and pasteurized milk plus 0.25 p.p.m. copper for the first and third days after pasteurization for the cows on the various feeding levels. Here again there is no correlation between the percentage occurrence of oxidized flavor and the feeding level. As can be seen from table 2 in the pasteurized milk the first day after pasteurization no oxidized flavors occurred in the −10 and +20 groups and the percentage occurrence in the −20 and +30 groups was practically the same.

TABLE 2

Percentage of samples of milk from cows of Jersey herd on various feeding levels that became oxidized from January 1937 to December 1937

Feeding level	No. of samples	Pasteurized		Past. plus 0.25 p.p.m. copper	
		1st day	3rd day	1st day	3rd day
−20	62	1.6	21.1	29.0	78.8
−10	20	0.0	31.5	45.0	84.2
Standard	46	2.0	26.0	47.8	73.9
+10	34	17.0	42.4	55.8	90.9
+20	47	0.0	8.5	36.1	89.5
+30	51	1.9	18.0	24.4	83.6

Occurrence of Oxidized Flavors Due to Seasonal Variations

Considerable experimental evidence has shown that during the winter months the development of oxidized flavors greatly increases in milk and after the cows are on pasture or are fed green feed this flavor practically disappears. There is generally a carry over in the effects of the pasture or green feed for 15 days to a month after it has been discontinued.

Kende (2), Guthrie and Brueckner (3), Thurston (4), Greenbank (5), Anderson (6) and Dahle (7), have shown that there is much less tendency for the development of oxidized flavors in milk produced in the summer

months than that produced in the winter months. However, Kende states that "There is no definite correlation between the presence of the reducible material in milk and the feed supplied to the cows."

The seasonal trend in the development of oxidized flavors was followed in this experiment in the raw and pasteurized and pasteurized plus copper milks. Figure 1 gives the percentage occurrence of oxidized flavors in the milk from all of the cows of the station Jersey herd from January, 1937, through December, 1937. The percentage occurrence of oxidized flavor is shown in graph form for the milk from individual cows the first and third day after pasteurization without added copper and with 0.25 p.p.m. copper added. The raw milk first day after milking is not shown since only one sample developed an oxidized flavor the first day after milking for one scoring period only.

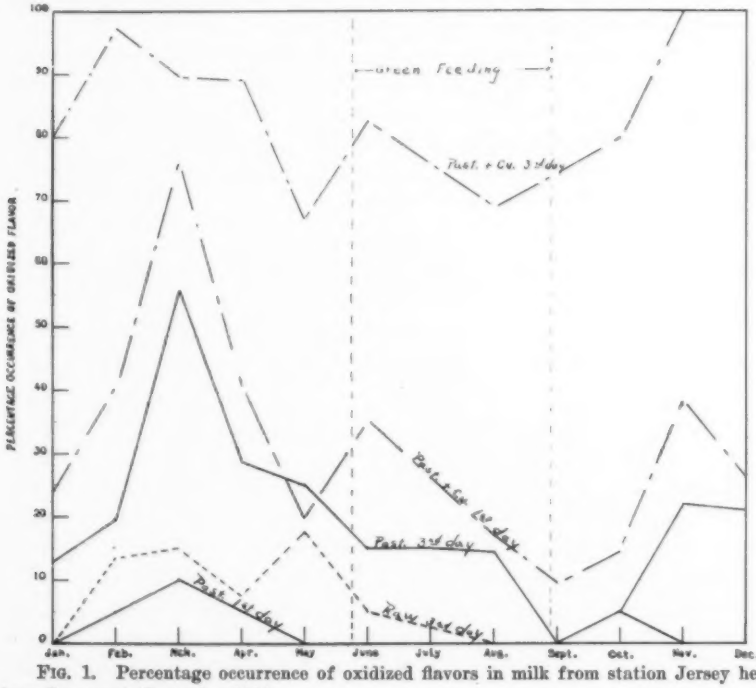

FIG. 1. Percentage occurrence of oxidized flavors in milk from station Jersey herd from January to December 1937.

The occurrence of oxidized flavor for the pasteurized milk the first day after pasteurization, as shown in figure 1 reached a high in March and was absent during May, June, July, August and September and recurred in October. The percentage oxidation curve for the raw milk judged the 3rd

day after milking was more variable than for the pasteurized milk judged the first day after pasteurization. The percentage occurrence of oxidized flavor started down in April, went up again in May, was zero in August and September and increased again in October and November. The raw and pasteurized milk judged in the flavor experiments the preceding fall did not show this increase in oxidized flavor in October and November. The milk scored on the third day after pasteurization shows somewhat the same general trends as that scored the first day after pasteurization but of course the percentage occurrence of oxidized flavor is very much greater. The pasteurized milk plus 0.25 p.p.m. copper on the first day shows a considerably higher percentage occurrence of oxidized flavor than the pasteurized milk without copper on the third day. The pasteurized milk plus copper on the third day ranges from 55 per cent oxidized flavor in September to 100 per cent in November and December. Both of the pasteurized plus copper curves go down in May and then for some unknown reason go up in June and then drop off to a low in September.

Since the period in which the cows received green feed was from May 24 to September 27 the change in the percentage occurrence of the oxidized flavor cannot be attributed entirely to the change of feed. The percentage occurrence of oxidation started to drop off in April prior to the time the cows received any green feed.

Occurrence of Oxidized Flavor in Milk of Heifers

During this experiment 6 heifers freshened and they were included in the experiment. Two of these heifers freshened the last of February, two in April, one the last of May and one the last of August. The milk from these heifers especially at the beginning of their lactation period seemed to be more susceptible to the development of oxidized flavors than the milk from other cows with the exception of the one freshening the last of August. Since this difference was noticeable at the time of scoring the milk, the percentage occurrence of oxidized flavor of the milk from these heifers has been compared with that of the milk from six mature cows picked at random for a similar seasonal period. Of 58 samples of pasteurized milk from the heifers scored the first day after pasteurization 4, or 6.8 per cent, were oxidized whereas none of the 57 samples from the cows were oxidized. The same comparison of the same milk the third day after pasteurization showed 14 out of 57 samples, or 24.5 per cent, oxidized for the heifers and 7 out of 58, or 12.0 per cent, oxidized for the cows. A comparison of this same milk plus 0.25 p.p.m. copper scored the third day after pasteurization showed that 84.4 per cent of the milk from the heifers was oxidized and 79.3 per cent from the cows. There are not enough results to prove that the milk from heifers is more apt to develop oxidized flavors than the milk from older cows but nevertheless the comparative difference is striking enough to be of considerable interest.

CONCLUSIONS

The flavor of fresh milk and its keeping qualities as indicated by the percentage occurrence of oxidized flavor and the numerical score in aged milk was not influenced by the level of feeding under the conditions of the experiment.

The occurrence of oxidized flavor was considerably less in summer months than in winter months but there was not a definite correlation between the exact period of feeding green cut legumes and the occurrence of oxidized flavors.

The milk from first calf heifers showed a higher incidence of oxidized flavors than milk from older cows but the data were not considered sufficient to draw definite conclusions even for the one herd in which all of the data for this study were obtained.

REFERENCES

(1) J. C. Hening and A. C. Dahlberg. The effect of feeding mangels or dried beet pulp to cows on the development of oxidized flavor. J. Dairy Sc. 21: 345–352. 1938.

(2) Kendi, S. Untersuchungen über, olig-talgige, schmiregelige Veranderungen der Milch. Milchwirt. Forsch., 13: 111–143. 1932.

(3) Guthrie, E. S., and Brueckner, H. J. The cow as a source of oxidized flavor of milk. Cornell Agr. Exp. Sta. Bull. 606, pp. 1–10. 1934.

(4) Thurston, L. M. Oxidized flavor in milk. Proc. Int. Assoc. Milk Dealers. Lab. Sec., pp. 121–141. 1935.

(5) Greenbank, G. R. Control of the oxidized flavor in milk. Proc. Int. Assoc. Milk Dealers, Lab. Sec., pp. 101–117. 1936.

(6) Anderson, J. A. The cause of oxidized and rancid flavors in raw milk. Proc. Int. Assoc. Milk Dealers, Lab. Sec., pp. 117–135. 1936.

(7) Dahle, C. D. The oxidized flavor in milk from the individual cow. Penn State College Sta. Bull. 347, pp. 3–30. 1937.

ROUGHAGE QUALITY AND QUANTITY IN THE DAIRY RATION, A REVIEW

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INTRODUCTION

Roughages are characterized chemically by a relatively large percentage of crude fiber which forms the framework of the plant (13). According to Morrison (350) roughages are feeds which are high in fiber and therefore low in total digestible nutrients. Such feeds as hay, corn fodder, straw, silage and pasture belong to this class. Some of the low-grade milling by-products, such as oat hulls, ground corn cobs and cottonseed hulls are roughages rather than concentrates, because they are high in fiber and furnish very little nutrient per unit of dry matter. Roughages may also be defined as feeding stuffs which contain a relatively small amount of net energy (or digestible nutrients) in a large bulk and contain a large percentage of crude fiber. Roughages include the vegetative part of plants as well as feeding stuffs of low total digestible nutrient content on a dry basis.

Armsby (13) and Morrison (350) used the following classification of feeding stuffs: (a) roughages or coarse fodders; (b) roots and tubers, and (c) concentrates.

The dairy cow, because of her spacious digestive tract which is adapted to the handling of large amounts of roughages, is the most important domestic animal to consider in a greater roughage program. The trend toward soil conservation and the closing of the spread between the price of dairy products and feeding concentrates has stimulated a world-wide interest in greater use of home-grown roughages.

The importance of using more home-grown feeds, especially legume hay and corn silage, in the ration of dairy cattle was emphasized by Lane (290) in 1902. Fraser (155) stressed more milk per acre by using home-grown feeds, especially alfalfa and corn silage.

The magnitude of the roughage problem is shown by data reported in the U. S. Census of Agriculture for 1935, which is presented in Table 1.

The use of roughage as a feed for dairy cattle depends on the amount of roughage consumed, chemical composition, digestibility, balance of nutrients and economy. The literature pertaining to the subject matter of this review is so voluminous that a detailed survey cannot be given here.

ROUGHAGE CONSUMPTION

In order to utilize more roughage in the feeding of dairy cattle, further knowledge concerning the factors affecting the consumption of various

TABLE 1

Roughages grown in the United States

Total acres in farms January 1, 1935		1,054,515,111	
Pastures	1934	*Acres*	
Plowable pasture		97,579,038	
Woodland pasture		108,095,711	
Other pasture		311,225,652	
Total		517,890,401	(40% of total farm acreage)
Hay	1934		*Tons*
Alfalfa		11,669,135	18,742,098
Sweet clover and Lespedeza hays		2,564,667	2,306,944
Timothy and clover		19,978,691	16,346,092
Annual legumes saved for hay		9,500,946	7,970,423
Small grains cut for hay		6,980,258	4,920,725
All other tame and wild grass cut for hay		17,930,813	11,798,065
Total		68,624,510	62,084,347
Sorghums for forage			
Silage, hay and fodder		7,909,269	7,452,897
Corn for silage (1933)		4,425,000	

roughages is imperative. The food capacity or appetite of an animal is the total amount of dry matter actually consumed when the animal is offered as much as it cares to eat (354).

Food consumption is affected by factors inherent in the animal such as size, age, health, psychological factors, inheritance, exercise and milk production; as well as factors inherent in the feed and environment such as palatability, amount of food offered, bulk of the ration, balance of the ration, and environmental temperature.

Palatability of Pasture.—A vast amount of research has been devoted to the study of the palatability of different pasture plants, usually by the cafeteria method. Palatability has often been confused with the consumption of large quantities of dry matter. As has been pointed out, palatability is but one factor responsible for a large food intake. A food may be consumed in large quantities yet it may not be very palatable. For instance, a silage mixture of 20 parts sweet clover and one part corn was not relished by cows, although when forced to eat it, one cow consumed up to 94 pounds of this silage per day which contained 40 per cent dry matter (95). Two other cows consumed 60 pounds per day for 126 days and the fourth animal refused the silage entirely after 30 days. On the other hand, a food may be very palatable but a small amount may give the animal a feeling of satiety. Nitrogen fertilizers have been shown to increase the palatability of the grass (106) and lime has been shown to increase the palatability of pasture herbage (426, 67, 89). Godden (164) studied the chemical composition of the natural uncultivated pasture herbage actually "eaten" and herbage from the same area which was not "eaten." The grass which was eaten was

higher in calcium, phosphorus, sodium, potassium, chlorine, and nitrogen and lower in fiber than the grass which was not eaten.

Winter grass compared with spring or summer grass was found to be unpalatable (553). Frost with its accompanying browning effect was the most important factor leading to the reduction in palatability.

Palatability is conditioned by mechanical state and not by taste (264). Reed canary grass which was the least palatable was found to be the least tough as measured by the breaking strength of the leaves (7). Semple and associates (430) state that palatability depends on the kind of plants, their tenderness, stage of maturity, density of the plants, and climatic and soil conditions. Livestock usually select plants which contain relatively high percentages of minerals.

Palatability of Hay and Silage.—Foster and Merrill (143) in 1889 and Mills (338) in 1896 reported that the relative palatability decreased as the alfalfa plant approached the fuller stages of bloom. Waters (501) using the free choice method with dairy cows reported that there were no significant differences in the consumption of the first three cuttings but that the fourth and fifth cuttings were less palatable. Cattle preferred white Australian wheat hay cut in blossom to hay of the same variety cut at later stages of development and such hay became less palatable as complete maturity was approached (219). Milking cows refused more of the second cutting than the first or third, and at times consumed the second cutting of alfalfa very reluctantly (66). Sotola (443) did not observe any difference in the palatability of the various cuttings of alfalfa. Prairie hay cut in July was more palatable to steers than that cut in October (71). The palatability of Sudan grass hay decreased with the increased maturity at the time of cutting when fed to dairy cattle (96).

Unfavorable curing conditions also decreased the palatability of Wyoming hay (521). Wyoming native hays cut early in the haying season or those which had plenty of water late in the season were as palatable as the best alfalfa. The palatability of irrigated alfalfa decreased with advance in bloom, with the exception of the second cutting. The relative palatability of Wyoming native hays was closely associated with the sugar content but alfalfa hay did not show this relationship.

The relative palatability of different U. S. grades of alfalfa was tested with steers. The palatability of the alfalfa hays used was independent of the grade of hay. The U. S. No. 3 hay which was coarse and stemmy was more palatable than the No. 1 and No. 2 hays (12).

The palatability of various silages was studied by Westover (515).

Palatability as an index of nutritive value of roughages has probably been overemphasized since it is not always a criterion of dry matter consumption.

Dry Matter Consumption on Pasture.—Although it is very important to

know the amount of dry matter that cattle will graze under various conditions, there is a paucity of data in this regard. Helms (218) reported that two lots of six cows each were tethered on grass within a large measured circle. At the end of the day the grass left within the circle was cut and weighed. The trial lasted 14 days. The cows consumed about 155 pounds of grass per head per day. Milk production did not influence the amount of grass consumed since the dry cows ate as much as the heavy milkers.

Graves and associates (172) fed grass clipped from irrigated pastures to four Holstein-Friesian cows for periods of 15 to 55 days. The average daily consumption by individual animals for an entire period varied from 122 pounds for the smallest cow to 152 pounds for the largest cow. The results obtained with a cow which was switched back and forth from pasture to grass clippings indicated that cows do not consume as much dry matter while grazing as when fed grass clippings.

A cow will graze about six per cent of the immature grass stand on one acre of ground per day and the limit of her capacity is about 150 pounds of green grass or 30 to 35 pounds of dry matter depending on her size (555). Cows will eat enough immature grass when the pasture is at its best for maintenance and the production of well over a pound of butterfat daily.

Hay and Silage Consumption.—Dairy cows consumed more of the better grades of alfalfa, timothy and soybean hay than they did of the poorer grades (559). When cows were changed from immature grass to mature hay or silage, a prompt decline resulted in consumption and production (171, 172). More dry matter was consumed in the form of hay than as silage.

When different amounts of corn silage and silage of different dry matter content were fed, the cows adjusted their hay consumption to the quantity of dry matter consumed in silage. The total roughage dry matter intake was not greatly affected either by the silage quantity, the proportion of ear, total dry matter, or water in the ration (516).

Willard (521) found that cows increased their hay consumption with increased allowance and that the consumption of hay tended to increase with the increase in concentrate allowance and vice versa. He worked out a method of determining the index of a cow's intake of hay. Unfavorable curing conditions produced a decrease in consumption of Wyoming hays. The sugar content did not appear to bear a close relationship to the amount of alfalfa hay eaten while the opposite was true of native hays. There was no relationship between the grade and the amount of alfalfa hay consumed.

The average daily amounts of hay consumed by beef cattle in three winters as calves, yearlings, 2-year-olds were: alfalfa and cane hay 24.6 pounds; alfalfa and prairie hay, 22.4 pounds; alfalfa hay, 21.5 pounds; cane hay, 20.4 pounds; prairie hay and cane hay, 14.4 pounds; and prairie hay, 16.8 pounds. Beef calves fed alfalfa alone consumed 16.3 pounds while those fed native hay consumed only 10.2 pounds daily (250).

Reed and associates (401) placed heifers on alfalfa alone at six months of age. During the first and second years the heifers consumed an average of 7.8 and 15.7 pounds of hay daily respectively. A lot receiving alfalfa and corn silage consumed about the same amount of hay-equivalent as the lot on alfalfa alone. Both groups were subnormal in weight at two years of age. Willard (523) concluded that calves may make desirable growth when fed high quality alfalfa alone as early as nine months of age. Bender and Bartlett (41) fed 18 heifers from six months of age to first calving on roughage alone (hay and pasture). These animals weighed 1052 pounds before freshening and were normal in height. The Montana Station (345) reported that heifer calves after being weaned in the fall and given a full feed of alfalfa hay during the winter consumed 12.7 pounds per day. The next winter as 2-year-olds these heifers consumed 24.5 pounds of alfalfa per day.

Milking cows which ate 13 to 14 pounds of alfalfa daily consumed only 5.7 pounds of reed canary grass hay (16). The poor appetite for reed canary grass was attributed to lack of palatability. Knott and Hodgson (278) in experiments with 41 cows on an all roughage ration found that there was little correlation between the dry matter consumption and age or weight or between age or weight and production, but that there was a correlation between milk production and dry matter consumption. The cows used in this experiment consumed as dry matter 22.2 pounds of grass hay, clover hay and silage; 25.7 pounds of alfalfa hay; 19.2 pounds of grass and clover hay; and 18.3 pounds of silage per 1,000 pounds of body weight daily.

A phosphorus deficiency is manifested by a decreased appetite for roughage (248). Kleiber (275) emphasized the importance of determining food capacity on a standard ration to be used as a criterion for estimating the breeding value of an animal. He stated that it is reasonable to assume that systematic breeding on the basis of relative food capacity would result in an increase in the economy of animal production.

As the factors affecting dry matter consumption become known and the quality of hay and silage improve, the amount of roughage consumed may be expected to increase. The old thumb rules of feeding were based on the consumption of two pounds of roughage equivalent per 100 pounds of body weight. Consequently, a revision of the rules for roughage feeding means a revision downward of the old thumb rules for grain feeding and greater use of home-grown roughage. The results summarized in Table 2 suggest that most cows will consume from 2.5 to 3.0 pounds of hay per 100 pounds of body weight.

CHEMICAL COMPOSITION AND FEEDING VALUE OF ROUGHAGE

The chemical composition of roughages depends on the botanical composition, the stage of maturity, the type and fertility of the soil, the method of conservation, as well as the climatic conditions.

Effect of Stage of Maturity.—Deetz (97) in 1873 studied the chemical

TABLE 2

Roughage consumption by lactating dairy cows

Source of data	Kind of ration	Wt. of animal	Av. daily consumption				Av. daily roughage consumption per 100 lbs. body weight
			Hay	Silage	Hay equiv.*	Grain	
		lb.	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
Kansas (401)	alfalfa alone 1st lact.	859	29.4				3.4
	alfalfa alone 2nd lact.	976	31.3				3.2
	alfalfa & corn silage 1st lact.	935	13.4	31.5	23.9		2.6
	2nd lact.	1077	15.4	39.2	28.5		2.6
	alfalfa, corn silage, light grain 1st lact.	1055	13.4	29.1	23.1	4.1	2.2
	2nd lact.	1112	12.8	32.3	23.6	5.3	2.1
	alfalfa, corn silage, heavy grain 1st lact.	983	11.7	23.3	19.5	5.2	2.0
	2nd lact.	1101	14.0	35.0	25.7	8.4	2.3
Nevada (212)	alfalfa alone (4 cows)	1355	36.9				2.7
	alfalfa and grain (4 cows)	1371	34.0			6.0	2.5
Oregon (258)	alfalfa alone (long) 14 cows	985	30.0			0.6	3.0
	alfalfa alone (chopped) 9 cows	1045	32.2			0.2	3.1
	alfalfa (long and grain) 7 cows	888	18.6			10.1	2.1
U.S.D.A. (173)	alfalfa alone (15 cows)	1226–1332	35.6–44.2				2.8–3.6
	full feed (15 cows)			24.4		11.4	
Ohio (343)**	heavy hay (Holsteins)		30.0	15.0	35.0	5.0	
	light hay (Holsteins)		15.0	42.0	29.0	8.4	
U.S.D.A. (172)	grass clipped, fed green 1929	1368			35.7		2.6
	grass hay	1369	40.4				3.0
	grass silage	1280			28.7		2.2
U.S.D.A. (171)	grass hay	1444	44.5				3.1
	grass silage	1335			33.4		2.5

* Hay equiv. = hay plus $\frac{1}{3}$ of silage.

** alfalfa – timothy.

composition of perennial rye grass cut at various stages of development. The protein declined sharply from May 6 to May 20 and more slowly thereafter. The calcium and phosphorus also fell somewhat during this period but did not change much later.

Kellner (266) in 1879, Jordan (261) in 1882, and Wilson (525) in 1884 reported that the nitrogen and ash of the timothy plant were higher in the early stages of maturity and decreased in the ripening stages but that the reverse condition prevailed with respect to the nitrogen-free extract. Ladd (288) studied the chemical composition of the timothy plant at four stages of growth. He reported an increase in sugar and starch after blossoming. The important fact that immature grasses are high in protein and low in fiber and that the percentage of protein declines and the crude fiber increases with maturity was observed by Richardson in 1883 (406).

Morse (351) in 1888 cut timothy grass at various stages of maturity. The ash was more abundant during the rapid growth of the plant than after the growth had ceased. The ether extract decreased until blossoming, then increased until the seed began to form, when it again decreased, reaching its lowest point as the seed began to harden. The crude fiber increased steadily, with two exceptions, until the formation of seed, after which there was a slight decrease. The nitrogen-free extract remained nearly constant after the grass had nearly reached its full height. Crude protein steadily decreased with the development of the plants although it remained nearly constant after the bloom began to fade. Dry matter steadily increased until the plant formed seed. The young grass was richer in fat and protein, whereas mature grass was richer in carbohydrates or fiber and nitogen-free extract. Timothy yielded the largest amount of digestible protein when cut at the beginning of bloom. The total amount of digestible matter was largest when cut at the beginning of bloom. Armsby and associates (15) in 1888, Crozier (85) in 1894, and Ellett and Carrier (119) in 1915 determined the chemical composition of pasture grass cut at the grazing stage of growth. The protein varied from 12.4 to 21.9 per cent on the dry basis and the crude fiber varied from 18.2 to 41.2 per cent.

Mortimer and Ahlgren (352) investigated the chemical composition of pasture grass cut about every two weeks throughout the season, with and without various fertilizers. The grass usually contained about 20 per cent protein on the dry basis.

The composition of blue grass cut at different stages of maturity was studied by Peter (377) in 1900. His results were similar to those reported by other investigators for other crops. Woodman and associates (551) studied the chemical composition of pasture grass on a dry basis. The protein varied from 20.6 to 26.2 per cent, ether extract from 3.95 to 6.41 per cent, nitrogen-free extractives from 35.2 to 50.6 per cent and crude fiber 10.9 to 17.7 per cent. These results were amply confirmed over a period of years (539,

541, 545, 549, 550, 551, 552, 116). The composition of grasses with development was also determined by other investigators (40, 108, 225, 375, 133). Similar results were reported for cereal grasses (446).

The seasonal variation in the tannin content of *Lespedeza sericea* showed that the tannin increased to about the middle of June and then leveled off. Most of the tannin was in the leaves (72). The authors regarded the tannin content of plants as a factor affecting palatability.

The chemical composition of many grasses at the before heading, full bloom and seed stages was determined (239). Timothy contained 12.8 per cent protein before heading and 5.9 per cent at full bloom stages of maturity. The crude fiber showed an inverse relationship to that of protein. Similar results were reported for brome grass, slender wheat grass, western wheat grass and crested wheat grass. The average total sugar content for these grasses before heading, bloom and seed stages was 10.5, 6.2 and 3.9 per cent on a dry basis respectively.

These workers also reported the sugar content of grasses on the dry basis as dextrose. The results are shown in Table 3.

TABLE 3

Sugar content of grasses (calculated on dry basis as dextrose)

	Total sugars			Reducing sugars		
	Before heading	In bloom	Seeds ripe	Before heading	In bloom	Seeds ripe
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Brome	11.07	7.98	4.22	6.67	3.65	2.06
Timothy	13.56	7.77	3.80	8.52	5.60	1.49
Western wheat	8.22	4.14	4.83	5.35	2.41	1.50
Slender wheat	9.30	4.73	2.87	6.84	3.49	1.34
Average	10.54	6.16	3.93	6.84	3.79	1.60

This phase was studied because the high sugar content of roughages is sometimes associated with palatability. The high quality of hay made from immature plants may be associated with the increased sugar content. These workers stated, however, that because of the solubility and ease with which it is fermented much of the sugar may be lost in the curing of grasses for hay under unfavorable conditions.

Capen and LeClerc (65) in Alaska studied the change in composition of native sedge, red top and cottongrass at various stages of maturity. The protein and total sugar in the dry matter decreased with maturity while the crude fiber increased. The decrease in sugar did not occur until rather late in the season.

Phillip and Goss (383) determined the composition of barley plants at different stages of growth in oven-dried material. The results are shown in Table 4.

After an initial increase, the percentage of ash and nitrogen declined

TABLE 4

Composition of barley plants (dry basis)

Age in days	Ash	Protein	Pentosans	Cellulose	Lignin
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
7	13.68	.....	9.0	.....	1.48
21	16.48	38.0	9.3	19.0	2.31
35	14.20	24.1	11.5	21.9	2.88
49	10.12	12.2	12.8	28.6	5.10
63	8.66	9.9	19.2	28.7	6.80
77	7.77	6.1	22.8	30.3	6.97
86	7.49	3.7	23.9	31.6	7.74

steadily as the plant matured. The percentage of cellulose increased rapidly as the plants grew older. The percentage of lignin, as well as the methoxyl in the lignin, increased in a regular manner as the plants developed and matured. The lignin in young plants differed from the lignin of mature plants in that the former contained a much smaller percentage of methoxyl. As the plants matured not only did the percentage of lignin increase but there was also a rapid methylation of the hydroxyl groups of the lignin. In the mature plants, 75 to 80 per cent of the firmly bound methoxyl groups were found in the lignin. This paper gives references to the early work on the subject.

The chemical changes which take place in rye grass with maturity were studied by Norman (368). Cellulose and lignin increased markedly as the plant approached maturity. Protein, pectin and fructosan decreased as the plant matured but the furfural from hemicelluloses did not exhibit a definite trend. A peak of 30 per cent of levulosans during early development was an interesting observation.

The chemical composition of the alfalfa plant at various stages of maturity was investigated by Widtsoe in 1897 (517). In the spring when the alfalfa was 6.5 inches high, the protein and fiber were 28.0 and 12.3 per cent respectively, on the dry basis. At the early bloom stage these values were 16.3 and 30.5 per cent and in late bloom they were 10.7 and 42.3 per cent respectively. The chemical composition of the second and third cuttings were determined in a like manner. Widtsoe also studied the variation in the chemical composition of leaves and stems of alfalfa. Continuing this investigation, Widtsoe and Stewart (518) reported that the water soluble constituents in early, flowering and later periods for the first crop were 21.9, 17.6 and 11.3 per cent respectively. The hexose, hexobiose, dextrin, starch, pentosans, crude fiber, ether extract, and protein fractions at various stages throughout the season were determined. There was a decrease in sugars, dextrin and protein fractions with maturity. Starch, pentosans and ether extract showed no significant trends but the crude fiber increased markedly.

The effect of maturity on the chemical composition of alfalfa was shown by Dinsmore in 1907 (104). The results were similar to those reported by

TABLE 5

Composition and feeding value of pasture grass and alfalfa cut at different stages of maturity (dry basis) compared with cereal grains (306, 350, 540, 550, 552, 549, 547, 542, 548)

	Protein	Co-ef. of dig. of prot.	Dig. protein	Fiber	Co-ef. of dig. fiber	N. F. E.	Co-ef. of dig. N. F. E.	Co-ef. of dig. org. mat.	Starch value
	per cent		*per cent*	*per cent*		*per cent*			
Pasture									
Cut weekly	24.7	81	20.0	15.4	76.7	44.79	81.5	79	67.7
" every 2 weeks	23.5	80	18.8	15.9	81.3	44.53	82.8	80	69.8
" " 3 weeks	21.1	79	16.7	17.2	79.2	46.68	83.5	80	69.4
" " 4 weeks	19.4	76	14.7	21.2	81.7	46.27	82.8	80	67.1
" " 5 weeks	18.3	74	13.6	21.9	82.1	47.18	79.1	77	64.7
Good meadow hay	13.8	63	8.7	25.8				65	45.2
Poor meadow hay	7.5	45	3.2	33.5				52	24.0
Alfalfa									
Prebud	25.3	84	21.3	22.1	63.7	38.13	79.8	76	59.8
In bud	20.4	76	15.5	23.9	46.3	42.22	74.2	66	50.8
In flower	17.2	74	13.0	29.7	42.6	39.35	70.2	60	42.4
Average alfalfa	14.2	74	10.5	29.5	50.8	40.91	73.7	.....	33.0
Cereal Grains									
Oats	12.4	78	9.7	10.9				70	64.0
Barley	11.5	78	9.0	4.6				88	74.0
Corn	9.6	74	7.1	1.9				9	84.0

Widtsoe and Stewart (518) for protein, ether extract and crude fiber, except that the variations were more pronounced, due to the fact that the samples were collected earlier in the season. Similar results were reported by Woodman and associates (547). The chemical composition of legumes at various stages of maturity has been reported by Sotola (443). Hunt and associates (251) also showed the effect of the stage of maturity on the chemical composition of alfalfa hay. Several other investigators have studied the chemical composition of alfalfa cut from bud to seed stages of maturity (420, 174, 272, 443). The results likewise show that the protein decreased and the fiber increased with maturity. Most investigations indicate that the greatest yields of dry matter and protein are secured with alfalfa when cut in the one-tenth to one-half bloom stage (420, 174, 273).

The changes in composition, digestibility and starch values of grass and alfalfa cut at various stages of maturity are shown in Table 5. The coefficient of digestibility of the organic matter of pasture grass cut every five weeks was 77 per cent compared with good meadow hay with a coefficient of 65 per cent. The data indicate that alfalfa cut in the bud stage has a much lower coefficient of digestibility than that cut in the prebud stage. This finding indicates that there is very little to be gained by cutting alfalfa before the one-tenth bloom stage, especially in view of the greater yield of dry matter and digestible protein per acre and less danger to the stand due to later cutting.

Hilton and associates (227) reported the yield of hay, dry matter, milk and butterfat per acre for early and late cut soybean hay. The results are presented in Table 6.

TABLE 6

Early versus late cut soybean hay for dairy cows

	Hay per acre tons	Dry matter per acre tons	Milk produced per acre pounds	Butterfat produced per acre pounds
Early cut*	1.614[1]	1.470	2,058	71.56
Late cut**	1.794[1]	1.608	2,451	92.62

[1] Yield on air dry basis.
* Cut when most of pods had formed and the lower pods were beginning to fill.
** Cut when pods were completely formed, the beans had practically reached their full development.

In this experiment relatively late cut soybean hay gave greater yields of hay, milk and butterfat per acre than early cut hay. As the soybean plant approached maturity it is apparent that the decrease in the percentage of protein in the leaves was more than compensated for by the increase in the percentage of protein in the pods.

The maximum quantities of total and digestible protein are present in timothy hay at about the full bloom stage of maturity. The digestible protein in relation to total protein declined rapidly after full bloom (471).

The composition of Sudan grass at successive stages of growth was investigated by Wright and Shaw (560) and is presented in Table 7.

TABLE 7

Composition of Sudan grass at successive stages of growth (dry basis)

Stage of maturity	Dry matter	Protein	Ether extract	Crude fiber	Reducing sugar	Non-reducing sugar	N. F. E.
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
2 ft. high & under	15.5	20.2	2.6	24.2	7.3	0.7	45.7
3–4 ft. high	13.9	15.5	2.4	26.0	11.3	2.1	48.7
4–6 ft. high	20.0	8.3	1.5	29.8	17.4	2.3	56.0
Early bloom stage	22.3	8.1	1.2	30.6	16.0	1.1	56.2
Middle bloom stage	34.2	5.0	1.1	33.7	11.0	1.5	58.8
Early dough stage	36.9	4.8	1.1	33.7	10.2	0.7	56.2
Advanced dough stage	37.7	4.8	1.3	33.4	10.3	0.3	55.8
Seed stage	41.3	5.3	1.2	33.4	5.6	0.3	55.4

The high protein content of the young plant, 3 to 4 feet tall, together with the crude fiber content suggests the reason for the popularity of Sudan grass for pasture.

The prussic acid content of young well fertilized Sudan plants may be sufficiently high to be toxic to cattle (49). This objection can be overcome by waiting until the plant is at least 18 inches high before turning cows on to it. There appears to be little danger from pasturing Sudan grass when the cows are in good condition. Leaves and young parts of sorghum plants are higher in hydrocyanic acid than the other parts of the plant. More mature parts are also lower in this respect (309).

The total dry matter yield of a few varieties of corn determined at various stages throughout the growing season showed that most of the dry matter production per acre is produced during the last few weeks of the growing season (1). The best variety of corn to use for silage is one which utilizes the growing season to the best advantage in the production of dry matter but at the same time reaches the dough stage of maturity most years.

Relation of Rainfall to the Composition of Roughages.—Alfalfa grown in a humid area generally has a higher phosphorus content than that grown in an arid area (482). The amount and distribution of rainfall are factors of paramount importance which influence the yield of both dry matter and protein (435, 8, 123, 109, 91). Midgley (331) concluded that since moisture is a limiting factor in the production of good pasture, it is evident that soil type has a marked effect on the quality and quantity of roughage. During dry seasons the phosphorus content of herbage cut at monthly intervals tends to be low and the calcium content tends to be high (109). Other investigators have also observed a decrease in the phosphorus content of the

herbage due to insufficient rainfall (111, 142). Severe outbreaks of malnutrition among cattle following a drought have been associated with insufficient phosphorus intake (474, 19, 464, 111).

Relation of Soil to Composition of Roughages.—Lawes and Gilbert (293) observed that the mineral content of forage plants is subject to wide variations as a result of soil conditions. Some of the early work which showed the relationship of the mineral content of feeds to the moisture content of the soil was reviewed by Eckles and associates (111) and Orr (371).

An application of complete fertilizer followed by later applications of nitrogenous fertilizer on a rotationally grazed pasture decreased considerably the percentage of dry matter in the grass and decreased slightly the percentage of crude fiber and calcium in the dry matter (11). The percentage of nitrogen, phosphorus and ether extract was increased, the nitrogen markedly so.

In most cases the application of 100 to 250 pounds of superphosphate per acre did not materially influence the phosphorus content of the dry matter (47). In some cases, however, the increase was as much as 40 per cent. Application of phosphorus to mixed herbage plots tended to increase the percentage of phosphorus in the hay. This may have been due to changes in type of vegetation as a result of phosphorus treatment. The phosphorus content of the grass was increased to an appreciable extent by phosphorus fertilizer (352). Phosphorus fertilizer increased the phosphorus content of white clover 10 per cent and Kentucky bluegrass 40 per cent. Calcium fertilizer added to acid plots increased the calcium content of brome sedge 19 per cent and Kentucky blue grass 36 per cent. Similar results were reported by other investigators (24, 483).

The use of manure or phosphorus fertilizer on alfalfa grown on a calcareous soil, high in total but low in available phosphorus, gave increased yields of hay. There was also a marked increase in the phosphorus content (388).

Fertilization increases the protein and phosphorus content of the pasture herbage (448, 295). The treament of pasture with large amounts of nitrogen and smaller amounts of superphosphates and potash gave outstanding production of herbage (53).

The application of a phosphate fertilizer increased the phosphorus content of grass, oats, and soybeans (341). Mather (310) reported that an application of 200 pounds of treble superphosphate was sufficient to give maximum yields in pounds of dry matter but that much larger applications were necessary to increase the phosphorus content significantly. He concluded that phosphate fertilizer could be profitably applied only insofar as it increased the pounds of hay per acre, and that the phosphorus required in a ration in excess of the quantity supplied in such a hay could be added directly to the feed.

Bone-eating habit in cattle was traced to phosphorus deficiency in the

hays and grasses eaten and was found to be confined largely to swampy areas, the grasses of which were shown to be much lower in phosphorus than the upland grasses (55). Triple superphosphate applied at the rate of 200 pounds per acre increased the yield of first cutting alfalfa by three per cent and increased the phosphorus content 10.4 per cent. The second cutting was increased 3.1 per cent in yield and 6.4 per cent in phosphorus content. Similar results were reported by other investigators (56, 5).

Jones and associates (260) studied the effect of fertilizing irrigated pastures. The addition of 300 pounds of 16 per cent superphosphate per acre increased the yield of dry matter 85 per cent. There was no effect on the calcium and phosphorus content of the herbage. The yield or composition of bench land and alluvial land pastures were not affected by nitrogen and phosphorus fertilizers (303). In an earlier experiment, Lush (304) reported that the addition of fertilizer to pasture resulted in a greater growth rather than effecting the composition of plants. Milk production from nitrate and phosphate pasture was doubled; and from cyanamid, trebled over unfertilized pasture. Nitrogen fertilizers increase the protein and decrease the fiber content of plants (130).

The average protein content of rotationally grazed pasture was increased from 22.6 to 25.3 per cent by intensive fertilization with nitrogen fertilizers (175). Enlow and Coleman (125) concluded that the protein content of pasture in a grazed condition can be increased and maintained at a somewhat higher level than ordinary by frequent light applications of nitrogen fertilizer.

Fertilizers improved the quantity and quality of the grasses but nitrogen fertilizer had an immediate pronounced effect (137). The cumulative effect of fertilizer is an outstanding factor. This system of pasture management lengthened the grazing season and increased the carrying capacity thus reducing the amount of barn feeding. The increase in the yield of dry matter was a more important result of the fertilizer treatment than any increase in the percentage of protein, calcium or phosphorus (180). The percentage of crude fiber was consistently higher in the fertilized crops.

Shutt and Hamilton (435) also reported that nitrogen fertilization increased the yields of dry matter and protein. Beaumont (30) increased the calcium, nitrogen and phosphorus in pasture grass by fertilization and the fertilized pasture grass was found to be more palatable. The fertilization of quack grass resulted in an increased growth associated with high protein content (99). The fertilization of blue grass increased the protein in the early part of the season but in early June the effect was slight (377).

Rabbits fed fertilized grass made good gains while those fed unfertilized grass made poor gains (81). The difference could not be detected by chemical analysis. The literature dealing on this subject was reviewed by Crampton (78).

Pratt and Holdaway (395) applied fertilizer to permanent blue grass sod which resulted in an increased milk production ranging from 31 per cent for the annual application of an incomplete fertilizer to 75 per cent for heavy applications of complete fertilizer. The fertilizer cost increased the cost of the total digestible nutrients. Crampton and Raymond (83) as a result of four years work with steers, stated that their results showed that fertilization practically doubled the carrying capacity of pastures. The protein, calcium, and phosphorus content of the herbage was also increased. These investigators stated that the nature of the protein is in some way changed by fertilization so that more rapid gains are obtained per unit of feed eaten.

Phosphate fertilization increased the white clover (52). The carrying capacity and the gains of the cattle paralleled the changes. Based on the unfertilized plot, 500 pounds of superphosphate produced an average increase of 64 per cent, while one ton of limestone together with superphosphate gave an additional increase of 50 per cent.

Soil fertility apparently plays an important role in the carotene content of plants. Guthrie (188) working with soybean plants, showed that an insufficient supply of nitrate nitrogen adversely affected the amount of both carotenoids and chlorophyll present. Virtanen and co-workers (488) showed that carotene is directly related to the facility with which the plant can utilize a given nitrogen supply and that nitrates are superior to ammonium salts. Furthermore, a maximum carotene content was reached when plants were grown at an optimum pH, which for wheat and peas, was assumed to be 6.5.

Thomas and Moon (467) investigated the carotene content of pasture grass and yield of carotene per acre as influenced by different fertilizer treatments. Sulphate of ammonia applied at monthly intervals produced marked increase in carotene content, yield of dry matter and total yield of carotene. Sulphate of iron applied monthly at a low rate, was without effect on carotene but seriously reduced yields of dry matter, while applications of $CaCO_3$ had no appreciable effect. There was a correlation between the carotene content of grass and the protein. A majority of the samples had a carotene-xanthophyll ratio of approximately 1 to 2.5. Nitrogen fertilizer increased and potassium fertilizer decreased the carotene content of plants (253).

Relation of Soil Type to the Chemical Composition of Roughages.—Grizzard (179) showed that chemical composition and the effect of fertilizer on alfalfa depends on the soil type. In general, the plants grown on soils not requiring applications of limestones showed increases in the phosphorus content of both stems and leaves with fertilizer treatments containing superphosphate alone or with potash. Plants grown on Isabella type of soil showed that all soil treatments containing limestone increased the nitrogen but tended to decrease the phosphorus content of alfalfa.

Nitrogen, phosphorus and potassium fertilizer applied alone or in com-

bination to the soils in Western Washington had no appreciable effect on the percentage of these elements in the alfalfa hay in the majority of cases but when applied to Eastern Washington soils the phosphorus and potassium content of the hay had a tendency to increase as a result of phosphate and potash fertilization (482). Similar results were reported by Grunder (180).

The phosphorus content of alfalfa hay grown on heavy soils was higher than that of hay grown on light soils (332). Superphosphate applications did not change the phosphorus content of field-grown alfalfa hay. The phosphorus content of field-grown red clover and sweet clover was increased by superphosphate fertilization. Limestone applications reduced the phosphorus content of alfalfa.

Plants are materially affected by the mixture of the soil on which they are grown (331). If the soils are high in available plant nutrients, it will be reflected in the chemical composition of the plants and likewise in the performance and physical condition of the grazing animals. Soil type greatly affects the kind of plant it will support. If sufficient moisture and minerals are present, more clover will be produced than when these essentials are lacking. Since legumes contain more protein and minerals than grasses, it is evident that soils indirectly affect the chemical composition of the herbage by influencing the botanical composition.

The effect of the application of phosphatic fertilizer to several different types of soil on the phosphorus content of plants gave varied results (120). On some soils the application of phosphorus resulted in increased phosphorus content of the plants while on other soils no response was observed. The authors suggested that the phosphate content of hay may be increased by the application of phosphate fertilizers if the phosphate in the soil is either low in quantity or not readily available.

More crops respond to a nitrogen fertilizer than to fertilization by any other element. This is especially true of the grasses used for pasture and hay. The application of phosphorus to phosphorus deficient soils results in greater yields of dry matter but does not always increase the phosphorus content of the pasture or hay crop. The per cent of phosphorus in such crops is influenced by the soil type, amount of moisture, amount of available phosphorus, and probably by many other factors. In certain sections where the application of phosphorus in quantities sufficient for maximum dry matter production does not materially increase the percent of phosphorus, the feeding of a phosphorus supplement is indicated when a protein concentrate rich in phosphorus is not fed.

Greater returns can usually be secured by fertilizing hay crops rather than pasture. The fertilization of pastures frequently results in a peak production in the spring but does not aid in solving the summer pasture problem when the temperature is high and the rainfall is low. This may not be true for regions which have sufficient summer rainfall.

PRESERVATION OF ROUGHAGES

In regions where good pasture is not available all the year round the preservation of roughages becomes important. Grasses and legumes have usually been preserved as hay while such roughages as corn, sorghums and sunflowers have been conserved as sun-cured roughage and as silage. Unfortunately there are many sections where it is impossible to make good hay due to unfavorable weather conditions.

Losses in Field Curing and Storage of Hay.—Wolff (492) in 1895 found that 20 per cent of the dry substance of hay may be lost by simply soaking in cold water and that clover hay suffered from rain more than meadow hay because from 25 to 40 per cent of its dry matter may be dissolved. He reported analyses by Ritthause at Möckern, Germany, on two samples of clover hay which were cut at the beginning of the flowering period from the same field at the same time. One was quickly dried and the other left for two weeks exposed to intermittent rains. The results are given in Table 8.

TABLE 8

Effect of rain upon the composition of hay

	Water	Crude protein	Nitrogen-free extract	Crude fiber	Ash
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Not rained on	16.0	14.6	36.1	25.3	8.0
Rained on	16.0	15.6	23.4	37.4	7.5

Headden (209) in 1896 reported the changes in the chemical composition of alfalfa hay damaged by rain. The results are given in Table 9.

TABLE 9

Effect of rain on the composition of hay

	Alfalfa dried in air bath Dry basis	Alfalfa in field May 28 to June 12, rainfall 1.76" Dry basis
	per cent	*per cent*
Ash	12.18	12.71
Crude fiber	26.46	38.83
Crude fat	3.94	3.81
Crude protein	18.71	11.01
Nitrogen-free extract	38.71	33.64

The weather during this time was cloudy and the temperature ranged from 72° to 81° F. The loss due to weathering as shown in table 9 is probably greater than usually occurs due to the fact that the hay which was not rained on was not field cured. Headden mentioned the mechanical loss of leaves and stems but attributed the changes in composition to the action of heat and moisture.

A sample of greenhouse barley was leached by soaking in water for several minutes. The losses were as follows: protein, 1.6 per cent; phosphorus, 36 per cent; potassium, 65 per cent; sodium, 52 per cent; magnesium, 45 per cent; and chlorine, 75 per cent. Very little leaching occurred in the plant until drying had taken place, whereas, if the rains came after the hay has been dried, the loss was considerable (294).

Westgate (514) sprinkled perfectly cured crimson clover hay with water to imitate rain for one hour on each of three successive days. The sprinkled sample lost about three-fourths of its sugar, one-ninth of its protein, and three-fourths of its ash. Rain washes out nitrogen-free extract; sugar, a constituent of the nitrogen-free extract; and amides (436). The weathering of clover, which included exposure to rain, resulted in a decrease in digestibility of each constituent except crude fiber (185). The loss of soluble constituents caused by rain may have been responsible for a greater part of the decreased digestibility. Bleaching and leaching apparently decreased the palatability of the bur clover. The effect of leaching on the chemical analyses was also studied (186). Loss of silica-free ash, 26 to 27 per cent; chlorine, 67 per cent in oat hay and 86 per cent in bur clover. Phosphorus loss was appreciable; nitrogen-free extract loss varied from 6 to 35 per cent; crude protein loss varied from 1 to 16 per cent, usually not very significant; ether extract was not affected and fiber increased.

Wiegner (519) working in Switzerland studied the losses due to hay making. The results are presented in Table 10.

TABLE 10

Losses of nutrients in hay making

	Percentage losses	
	Digestible protein	Starch equivalent
Dried indoors, no rain, no mechanical losses	13.8	22.6
Dried outdoors, no rain, leaf shedding	32.7	38.6
1–2 showers of rain	27.8	43.6
5–6 showers of rain	49.8	54.2
Average of all experiments in which it rained	40.4	49.7

Losses of starch equivalent and digestible true protein increased with the amount of rain falling on the crop in the field. In an extreme case, a loss of 62 per cent of the starch equivalent of the fresh crop and 45 per cent of the digestible true protein was reported (84).

The data in Table 11 were compiled by Watson and associates (511) and show the losses of dry matter, starch equivalent and protein equivalent in hay making.

The hay was meadow hay in all cases. The large losses of starch equivalent and protein appear significant.

TABLE 11

Losses arising during hay making with field meadow grass

Year	Weather conditions	Type of hay	Percentage of the original material		
			Dry matter	Crude protein	Starch equivalent
1932	excellent	early hay	20.5	17.6	31.4
	poor showers	ordinary	33.9	51.3	46.7
1933	fair	early hay	15.5	12.7	36.1
	excellent	ordinary	12.2	11.5	25.6
1934	very good	early hay	5.6	6.8	19.4
	excellent	ordinary	10.0	9.0	21.7
1935	very poor	early hay	30.5	20.2	51.2
	good	ordinary	1.2	2.4	12.6
Average		early hay	18.0	14.3	34.5
		ordinary	14.3	18.5	26.7

From a 2-year investigation in eight localities in Norway (412) it was found that the total loss of food nutrients was 20 per cent. Kiesselbach and Anderson (272) studied the effect of rain on the protein content of alfalfa hay excluding leaf loss. The results are shown in Table 12.

TABLE 12

Effect of rain on field cured hay

Number of comparisons	Exposure to rain	Hours required	Moisture content	Color	Quality leaves	Protein	Grade
			per cent	*per cent*	*per cent*	*per cent*	
Tests June 18							
14	no	74	28	48		16.9	2
14	yes	191	23	40		17.0	2
Tests July 11							
5	no	54	31	57	39.2	17.4	2
5	yes	136	31	32	39.2	18.6	3
Tests August 14							
2	no	44	17	65	38.0	16.4	1
2	yes	131	15	40	38.0	16.8	
Averages							
21	no	57	25	57	38.0	17.1	2
21	yes	153	23	37	37.9	16.5	2

Alfalfa dried in the sun had a higher total protein content that that dried in the shade (458). The loss in digestible constituents during drying in the field may vary from 20 per cent under favorable conditions to 50 per cent under adverse weather conditions (433). Sweet clover dried in the sun had a higher total protein content than hay that was dried in the shade (222). Alfalfa samples which were dried in the sun had a larger percentage of water soluble carbohydrate than those dried in the shade. Sprinkling decreased the water soluble carbohydrate for both the samples dried in the shade and

those dried in the sun. Weiske (512) noted that meadow hay held at a temperature of 100° F. was lower in digestible protein than that kept at atmospheric temperature even when kept at this temperature for two to four weeks. This change was somewhat more marked on the moistened hay both in chemical composition and in palatability.

Fleischmann (136) found that under the most favorable conditions of curing there may be no loss of dry matter. If the drying is not too rapid in uninterrupted sunshine there may be an actual gain in weight which may be ascribed to assimilation. Under less favorable conditions losses may occur and under very unfavorable conditions the loss of dry matter in harvesting may exceed 20 per cent.

A comparison of alfalfa and red clover hay dried in an oven, in the sun, and in the shade indicated that under such conditions fermentation does not take place to any great extent (222). Paturel (374) showed a loss of 15 to 35 per cent in dry matter of damaged alfalfa, clover and common hay. A feeding trial indicated a proportionate loss in feeding value. Cooke (76) found as an average of eight tests in Colorado that the loss in dry matter under ordinary methods of field handling varied from 5.1 to 26.1 per cent. The extreme values represented differences in weather conditions. Kenney (269) stated that the average loss in harvesting 41 lots of alfalfa in Kansas in 1914 was 12.43 per cent of the entire crop. The loss of leaves varied from 6 to 48 per cent.

Mechanical Losses.—The loss due to mechanical causes is a variable one. The shedding of leaves is the most serious due to the fact that the leaf is high in nutritive value. Salmon and associates (420) determined the leaf loss in harvesting alfalfa from 1914 to 1920. The results are presented in Table 13.

TABLE 13

Leaf loss in harvesting alfalfa hay

Stage of maturity	Per cent leaves	Per cent of total crop
Bud	19.1	10.1
1/10 bloom	14.5	7.3
Full bloom	20.4	10.1
Seed	22.2	9.3

Over this period 19 per cent of the leaves were lost which amounted to 9.2 per cent of the total crop. The leaf loss varied with the season ranging from 8.6 to 25 per cent of the leaves. When the conditions were unfavorable and the hay was handled carelessly, half of the total weight of the alfalfa and a much larger part of the feeding value was lost (511).

The plant when cut for hay is still alive and until the cell is killed as a result of drying, it still continues to breathe. The act of breathing causes a loss of carbohydrates. Further, though less serious, losses are due to the action of enzymes.

TABLE 14

Losses in hay making (519)

	Dry matter	Digestible dry matter	Starch equivalent
	per cent	*per cent*	*per cent*
Respiration	up to 10	5–15	5–15
Mechanical losses	5–10	5–10	5–10
Fermentation in the stack	5–10	5–10	5–10
Losses due to extra energy necessary to digest hay			10–15
Total	10–30	15–35	25–50

Newlander and associates (363) studied the percentages of the various nutrients lost or gained by different methods of conserving green alfalfa and timothy for winter use. The results are shown in Table 15.

TABLE 15

Nutrients lost or gained by different methods

	No. of tests	Dry matter	Ash	Crude protein	Crude fiber	Nitrogen-free extract	Ether extract
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Silage*	24	− 8	− 5	− 7	− 1	−15	+17
Sun-cured hay	4	−15	−21	−21	−12	−14	−28
Artificially dried hay	4	− 5	−10	−17	0	− 3	− 5

* Losses due to spoilage at top of silo are not included.

Watson (506) recently compiled the percentage losses in roughage conservation as shown in Table 16.

TABLE 16

Percentage losses incurred in conservation processes

Process	No. of tests	Dry matter	Starch equivalent	Digestible protein
		per cent	*per cent*	*per cent*
Hay making	39	22.1	43.9	34.6
Hay making with special appliances	96	17.4	38.2	25.3
Artificial drying	2	7.5	11.5	8.2
Ordinary silage	225	15.9	34.3	39.8
Stimuated (molasses)	34	11.7	22.9	10.0
Acidified silage	74	12.4	23.7	10.0

The time required for hay to reach 30 per cent moisture and the percentages of dry matter recovered by different methods of sun-curing were studied by Kiesselbach and Anderson (273). Hay cured in the swath throughout reached a moisture content of 30 per cent in 27 hours but lost

18.5 per cent of the dry matter. Hay which was cured in the swath for two hours and then cocked reached 30 per cent moisture in 32 hours and lost only two per cent of its dry matter. The data indicated that the most practical method was to cure for three hours in the swath and then put in a windrow. By this method 30 per cent moisture content was reached in 27 hours with a loss of only 1.7 per cent of the dry matter.

The size of the windrow affected the length of time required for hay to cure but did not affect the quality of the resulting hay (272). Also, hay windrowed 4, 8 or 24 hours after cutting, cured more rapidly than the hay which was raked immediately after cutting but not as rapidly as that cured in the swath. Partially swath cured hay graded higher than the hay from either of the other methods of curing. Higgins (222) emphasized the importance of curing hay so as to have the leaves and stems remain soft and tough.

Truninger (473) followed seven lots of hay in detail from the time of cutting to the time of storing. There were changes in dry matter ranging from a maximum loss of 11.3 per cent to a maximum gain of 1.3 per cent. The storage of these lots of hay in small stacks whose moisture content ranged from 23.4 to 39.1 per cent, resulted in further loss of 2 to 11 per cent or an average of six per cent for the seven lots. The chief loss occurred in the nitrogen-free extract, the changes in these constituents ranged from a loss of 40 per cent to a slight gain in two cases. Crude protein remained practically unchanged although there was a marked decrease in the coefficient of digestibility of the pure protein.

Losses in Storage.—Browning of hay resulted in a marked decrease in the digestibility of protein (237). Swanson and co-workers (457) studied the losses in making brown and black alfalfa hay by stacking partially wilted alfalfa having an average moisture content of about 40 per cent. The losses in protein, crude fiber, nitrogen-free extract, and ether extract were 32.7, 46.5, 45.4, and 63.6 per cent respectively. Black alfalfa produced as a result of fermentation was found to be quite inferior as a feed for steers to brown alfalfa or alfalfa of good quality and color. Steers on black alfalfa made an average gain of 1.45 pounds per day compared with 1.94 and 1.96 pounds respectively for brown and regular alfalfa hay.

This problem was recently studied by Hoffman and Bradshaw (235) in a series of seven large scale storage experiments. The samples of hay investigated contained 28 to 70 per cent moisture. The loss of organic matter ranged from 4 to 22 per cent with an average of 13 per cent. The loss varied with the maximum temperature which did not exceed 78° C. in this work.

The losses in crude fat ranged from 6 to 47 per cent. The loss of crude fat was accompanied by complete loss of carotene. The sugars suffered a severe loss and in several cases they were almost entirely destroyed. The losses ranged from 59.1 to 93.7 per cent indicating a very high degree of

active fermentation. Hemicelluloses as measured by the pentosan value underwent a loss of 13.9 to 52.1 per cent as determined by hydrolysis. Cellulose showed a loss ranging from 6.7 to 21.1 per cent in two experiments. Some samples showed a slight gain. Lignin showed gains, except in three samples, in which very small losses were recorded.

Spontaneous combustion of hay was attributed to the presence of pyrophoric iron produced by cellulose. Hay thoroughly exposed to the sun's rays must be richer in hydrocarbons is advanced as the reason why more stacks are destroyed by fire during a good hay season (292). Hay stack fires occur more frequently during a year of good conditions for hay making. The literature on this subject has been reviewed recently (565).

Woodward and Shepherd (557) studied the loss of dry matter during storage of hay finely chopped (one-fourth inch), coarsely chopped (three-fourths inch), and long alfalfa hays. These hays contained from 25 to 27 per cent moisture when stored. Approximately three times as much finely chopped and twice as much coarsely chopped hay could be put in a given space as long hay. The chopped hays lost all traces of green color during storage, whereas considerable of the green color was retained in the long hay. The carotene loss was extensive in all lots but somewhat greater in the long hays. The loss of dry matter during storage was highest (6.5 per cent) in the finely chopped lot. The long hay was more efficient than the chopped hays in tests with milking cows. These workers (432) also found that hay with 16 per cent moisture lost more green color and carotene when stored in a chopped form (three-fourths inch) than when stored in long form. There was no significant difference in milk production when chopped or whole hay was fed. The cows consumed slightly more of the chopped hay.

Hay of a distinct brown color did not result if the moisture content of the hay as stored did not exceed approximately 30 per cent (413). The maximum loss of dry matter was 22 and the average loss 14 per cent. Losses in organic matter included mostly the fats, sugars, and hemicelluloses. Protein and cellulose were lost under more destructive conditions.

Effect of Salt on the Microbial Heating of Alfalfa Hay.—According to Hill and White (223) the fact that sodium chloride inhibits the growth of certain microorganisms is well known. Shutt (434) observed that in every case hay to which salt was added during the storing process appeared brighter than hay stored unsalted. No appreciable chemical difference was noted. Feeding experiments indicated that 20 pounds of salt could be added per ton without any bad effects but when 30 pounds per ton were added bad physiological effects resulted.

Stuart and James (454) after studying the effect of adding one, two and five per cent salt to hay, concluded that salt added to moistened alfalfa hay will inhibit bacterial growth and will delay but not prevent mold development. This delay in microbial development may be long enough to permit

the curing of hay. The use of 1.5 per cent of salt added to long alfalfa hay averaging 35 per cent moisture had no appreciable effect in preventing or retarding spontaneous heating (413). Hartwig (201) reported that hay ranging in moisture content from 20 to as high as 40 per cent was not benefited by the addition of 12 to 24 pounds of salt per ton. The age old practice of salting hay does not appear justified from the standpoint of hay quality (413, 565).

Artificial Drying of Hay.—It is apparent that the loss of nutrients during hay making under ordinary conditions is rather great. This fact has stimulated an interest in methods of artificially curing roughages. A method of artificial drying was devised in 1894 by an English farmer named Neilson (385). By this method the green material was placed in rough stacks having a cylindrical open space at the center extending from the bottom to near the top. A pipe extending under the stack connected this open space to a powerful fan which sucked out the air, thus causing the outside air to penetrate the stack. The fan was operated from 15 to 60 minutes daily for from one to three weeks.

The Institute of Agricultural Engineering of the University of Oxford conducted a series of experiments on the artificial drying of hay crops in 1925 (254) by driving air with a fan through a tunnel into an open space under the stack of green material. Peas, beans and cereals were successfully dried by using air of atmospheric temperature. The conclusion was, however, that this method could not be depended upon under adverse weather conditions.

Recently Wylie and co-workers (561) left the hay in the field for a part of the first day until the hay contained about 45 per cent moisture. It was then stored in a loft equipped with a system of air ducts through which the air from a blower was forced upward through the hay or drawn down through the hay as desired. This process gradually removed the excess moisture and kept the hay at about the wet-bulb temperature. By blowing air through the hay during the day only, and allowing the excess moisture in the hay to move to the surface of the stems and leaves over night, curing was completed about as soon as by continuous blowing. The advantages claimed for this system are its cheapness and improved quality of hay.

In 1924 and 1925 the University of Oxford (254) dried hay with heated air. A temperature of 180° to 190° F. was not considered too high. Chemical analysis showed the feeding value of the hay dried artificially at these temperatures to be practically the same as that of the green plants and superior to that of hay dried under ordinary field conditions.

The data of Woodman and associates (539) and Watson (502) indicate that artificially dried young grass is in the class of concentrate food stuffs. Watson (502) also carried out an experiment using five cows in which artificially dried grass replaced grain in the ration for a period of 14 days. The

results indicated that the grass was about equal to the concentrates for milk production.

Digestion trials with dairy cows fed solely on artificially dried young grass and on fresh green young grass, showed on the basis of 90.2 per cent dry matter, that the total digestible nutrient contents of the dried grass were 64.47 per cent and of the green grass 63.46 per cent (364).

Newlander (360) from the results of a double reversal feeding trial with milking cows observed an increased milk and fat yield when artificially dried young grass was substituted for hay in the ration on total digestible nutrient basis. He concluded that at least average milk and fat production could be secured by feeding home-grown artificially dried young grass in lieu of purchased concentrates. The data indicated that milk production did not hold up as well when the concentrates were replaced by dried grass. Camburn (62) concluded that considering both milk production and body gain the total digestible nutrients in the dried grass were equal or slightly better than those in the grain mixture.

Hodgson and Knott (229) observed the following coefficients of digestibility for artificially dried grass by dairy heifers: dry matter, 67; crude protein, 75; nitrogen-free extract, 22; and crude fiber, 73 per cent. Artificially dried pasture herbage may be efficiently used for at least a part of the concentrate mixture of milking cows (277).

Newlander (362) reported the following digestible protein and total digestible nutrient contents of the following artificially dried roughages: corn silage, dried 3.73 and 67.7; corn silage, wet 4.57 and 68.24; oat hay, 10.5 and 70.57; Sudan grass, 12.44 and 65.25; soybean hay, 9.00 and 71.43; and millet, 8.05 and 67.96 respectively.

Watson and Ferguson (508) alternated two groups of milking cows between a ration of roots, hay and concentrates and a ration in which approximately eight pounds of artificially dried grass per cow daily replaced part of the concentrates, the two rations being adjusted so as to supply equal quantities of protein and starch equivalents. There were significant differences in milk and butterfat yields. The greater carotene intake in the dried grass resulted in a marked increase in yellow color of milk.

Newlander (361) determined the digestibility of artificially dried young Sudan grass. The dry matter, protein, fiber and nitrogen-free extract were 70, 64, 71, and 77 per cent digestible. The total digestible nutrient content on a dry basis was 58.9.

The nutrients of green alfalfa exposed to temperatures of 480° to 535° C. in a Koon type drier for 40 seconds were no less digestible than those of similar alfalfa dried in the field (197).

Watson (504) concluded that a feed of high digestibility and hence high feeding value could be produced at a drying temperature of 600° C. He estimated the loss of nutrients during dehydration at five per cent. Bartlett

and associates (27) reported that biological values of protein of young grass sun-dried, artificially dried at 300° F. and at 170° F. were 52, 67, and 62 respectively.

The digestibility of the various constituents of green grass, sun-cured grass and grass dried at various temperatures was studied (231). A temperature of 400° F. depressed the digestibility of the protein, dry matter, and nitrogen-free extract. The various temperatures used lowered the color.

The effect of varying lengths of time grass was exposed to air at 160°, 180°, and 200° C. was also investigated (503). The exposure of the dried material to hot air reduced the carotene and digestibility of the protein markedly at 160° and 180° C. when the time was greater than 10 minutes. With a temperature of 200° C. the losses were marked at 10 minutes.

Five Jersey heifers were started on artificially dried roughage alone at 12 months of age (167). They maintained slightly more than normal gains between 12 and 18 months. In another experiment 16 Jersey cows made 17 lactation period records on rations restricted to artificially dried hay and pasture. Their average production calculated to mature equivalent basis, for an average lactation period of 361 days was 6,333 pounds of milk and 329 pounds of butterfat. These same cows fed liberal amounts of grain in addition to artificially dried hay and pasture produced an average of 9,656 pounds of milk and 527 pounds of fat. On the roughage ration the cows produced 66 per cent as much milk and 62 per cent as much butterfat as they produced under the register-of-merit conditions. During the time that they received hay without pasture they consumed an average of 28.6 pounds of hay per cow per day, or at the rate of 3.44 pounds of hay per 100 pounds of body weight. The artificially cured hay was very palatable. Artificially cured hay which has not been exposed to the sun is deficient in vitamin D (33).

The problem of grass drying has recently been reviewed by Roberts (412). The temperature of the inlet gases may be as high as 700° C., under which conditions drying is extremely rapid, without causing any serious impairment of quality or feeding value, provided the drier is operated in such a manner that the material is removed from contact with the hot gases as soon as it is dry (537). Furthermore, under satisfactory conditions of drying, most of the carotene of the fresh grass is retained in the dried product and the use of the latter in the winter rations of dairy cows results in the production of a yellow butter comparable to that produced when the cows are on grass in the summer. Artificially dried alfalfa and soybean hays contained considerably more carotene than the same grades of hays cured in the sun (226).

The nutrients in properly artificially cured hay are well preserved during the curing process but the loss of carotene during storage at high temperatures is of about the same order as sun-cured hay. The most important dis-

advantage of artificial hay-drying methods now in use is the high cost. Low temperature, high windage in dehydration of hays may reduce the cost somewhat.

Conserving Roughages in the Silo.—The large loss of nutrients in the field-curing of roughages, especially during inclement weather has focused attention on the use of the silo. In the past corn and the sorghums were the principal crops ensiled. The literature pertaining to corn silage has been reviewed by Nevens (358). The trend toward soil conserving crops has raised the question of placing the grasses and legumes in the silo.

Early History of Grass and Legume Silage.—In 1887, the Vermont Experiment Station analyzed a sample of rowen silage made by a farmer (493). Peas and oats, Hungarian millet, clover, peas-vetch-oats, cow peas and soybeans and rye were ensiled and their feeding value studied (494, 495, 496, 497).

In 1896 Headden (209) compared alfalfa, red clover and pea-vine silage from the standpoint of chemical analysis. The alfalfa silage samples contained 30 per cent dry matter. Headden stated "It will seldom be advantageous for the farmers of this country to make their crop into ensilage, but if they should choose to, the ensilaged product, as shown above, will compare favorably with a very good quality alfalfa hay."

In 1900 Cooke (76) experimented with two batches of alfalfa silage, one with alfalfa put in whole as cut in the field, and the other with alfalfa cut in quarter-inch lengths. The whole alfalfa showed a spoiled layer around the side nearly all the way down. The silage at the bottom and middle was excellent and was greedily eaten by cows and calves. The loss in total weight was 10.7 per cent. The cut alfalfa was weighted with stone. When put in it contained 33.0 per cent dry matter. The silo showed two inches of spoiled ensilage on top and one-half inch on the sides at the time of opening. The loss in dry matter was 10.0 per cent. Shaw (431) in 1900 referring to legumes for silage said, "These can all be preserved with more or less success in the silo, but when preserved without mixing with other crops, in instances too numerous to mention, the success attained has been only partial."

Withycombe (530) in 1901 reported as a result of an investigation and observations in Oregon that legumes make good silage (clover, vetch and alfalfa). He stated that alfalfa should be harvested in full bloom for silage.

Clark (73) in 1913 following three years of experimental work, reported that clover silage gave good results. According to Upson (478) in 1915, alfalfa silage does not keep well, probably on account of a deficiency of fermentable sugar which is needed to form sufficient acid. Alfalfa mixed with sorghum in different proportions gave good results. Good silage was also made from alfalfa to which corn meal was added at the time of ensiling.

Woll (531) in 1917, stated that alfalfa silage was used to a considerable

extent with good results in California. The best alfalfa silage observed was made from alfalfa cut at the beginning of bloom. It was cut in the morning and left to dry in the field until noon. No water was added.

The most extensive early investigations with alfalfa silage were made by Reed and Fitch (400). They concluded that alfalfa alone makes a fair quality silage but that it should be fed within a few months as the quality deteriorates rapidly after the silage is several months old. The addition of material containing easily fermentable carbohydrates, such as corn meal, blackstrap molasses, or mixing with such crops as sorghum gave the silage better keeping quality and greater palatability. The cattle ate very little straight alfalfa silage. Alfalfa and ground corn were mixed 10 to 1 and the alfalfa and molasses 20 to 1. The alfalfa used was high in dry matter, ranging from 38 to 58 per cent.

According to Swanson and Tague (459) silage could be made from alfalfa alone if the absolute exclusion of air and retention of CO_2 were secured. They also reported that wilted alfalfa was more suitable than unwilted for making silage. Molasses was the most effective preservative for alfalfa silage. Germinated corn was better than sound corn.

Hunter (252) reported that alfalfa siloed alone underwent a typical silage fermentation which was caused by microorganisms practically identical with those from normal corn silage. When fermentable carbohydrate was added to the silo at the time of ensiling a good quality of silage was produced although bacterial flora was not changed. Alfalfa silage which was made with a fermentable carbohydrate supplement had a higher acidity. More amino nitrogen and more ammonia were formed in the alfalfa silage than in the alfalfa and carbohydrate silage which indicated that the carbohydrate was a protein sparer. The theory was advanced that proteolytic action which is responsible for the offensive odors characteristic of alfalfa silage was due in part at least to the inability of the acid producers to utilize protein as a source of energy in the absence of carbohydrates. Alfalfa ensiled alone or in combination with straw developed a typical acid fermentation and was unfit for feeding purposes (356).

The important factor which determines the keeping quality of alfalfa silage is the water content (110). For the best results, alfalfa should contain nearly 40 per cent of dry matter when put into the silo. The limits for good results seem to be between 30 and 50 per cent of dry matter. During a season of normal rainfall alfalfa will, as a rule, contain from 20 to 25 per cent of dry matter when in the stage usually cut for hay. During a period of abnormally low rainfall the dry matter may be as high as 40 per cent. In order that the plants may continue to grow and produce a good crop for the next cutting, it is necessary to cut the crop before it is sufficiently mature and to have the proper amount of dry matter to make good silage. For this reason, except when the crop is unusually dry and firm as a result of a deficiency of

rainfall, it is advisable to allow the alfalfa to lie in the field a few hours after mowing in order to eliminate some of the excess moisture. The proper stage at which to put alfalfa into the silo is when it is wilted but still not dry. In this condition, the leaves show the most effect of the drying, the stems should be green and pliable but not dry and brittle. If the material gets too dry before filling is completed, no hesitancy need be felt about adding water.

Alfalfa may be put into the silo with good results after having been rained on while curing for hay. If the alfalfa was cured, or nearly so, at the time rained on, it may be put into the silo at once after the rain ceases and under these conditions will have about the necessary amount of water to insure preserving qualities.

Fred and Peterson (158) studied the preparation of alfalfa silage according to the method of ensiling hay as reported by Samarani (421). The alfalfa was dried to 30 to 40 per cent water content and tightly packed and heavily weighted in a silo. They reported that the silage produced had a brownish-green color, a pleasant odor, and was readily eaten by cattle. The essentials for successful production of alfalfa silage by this method appear to be the reduction of water to prevent bacterial growth and the retention of sufficient living tissue to remove oxygen. According to Samarani, the principle of the preservation of the hay in the silo by this method depends upon the fact that the plant cells in a few hours transform the oxygen in the silo into carbon dioxide which prevents the growth of bacteria and thus does away with the heating of hay.

Casalis (68) reported good results by adding molasses to alfalfa in making silage. From 0.5 to 0.75 per cent of sugar was added to the material. Sugar is most economically supplied in molasses. Since molasses contains approximately 50 per cent sugar, 30 to 40 pounds of molasses diluted to a working consistency is added to each ton of green alfalfa. Some farmers applied the molasses mixture with watering cans, but others fed it through a blower and cutter. This process is known as the low temperature process and its application produces a fermentation at a temperature not exceeding 30° C. of a preponderantly lactic acid type which will suppress the undesirable microorganisms, such as butyric acid bacteria, responsible for the breaking down and decay of the valuable proteins in the crop. Two milking cows were fed a ration of alfalfa silage and corn silage exclusively for 138 days (95). Alfalfa silage was made with one part beet molasses to each 20 parts of first cutting alfalfa. The two cows showed a preference for corn silage at all times.

Swanson and Tague (460) concluded that silage can be made from sweet clover alone with less difficulty than from alfalfa alone. Dice (102) found that cows on pasture would not eat sweet clover silage made in stacks in any considerable amounts, but when off pasture it was well eaten as a substitute for corn silage. Sweet clover silage was 85 to 90 per cent as efficient for

milk production as corn silage in 20-day tests using five cows and five heifers (101). This difference was due to about 10 per cent wastage of the coarser stems of the sweet clover.

Rothwell (416) compared sweet clover silage with corn silage by using 21 cows during a test period of three weeks. The results indicated that 18,220 pounds of sweet clover silage, 206 pounds of grain and 218 pounds of hay were required to replace 18,271 pounds of corn silage.

A test on a large scale was made on a farm near the Missouri Experiment Station in which 70 acres of sweet clover were preserved in silos with excellent results (110). This crop which yielded about 10 tons to the acre was cut when in full bloom. Most of it was allowed to lie in the field until some of the water had evaporated before it was put into the silo. The silage which was well preserved proved to be very palatable for fattening cattle and was fed with entire satisfaction. A sample of typical silage taken from this source contained 35 per cent dry matter. No hesitancy need be felt in preserving sweet clover in the silo if desired. The same precautions should be taken concerning the dry matter content as suggested for other legumes.

If cut while at the first indications of bloom, or before, the green forage should be allowed to lie from three to six hours in the sun to reduce the moisture content. If the crop is more mature no drying is necessary. If through maturity of the plant or over drying, the sweet clover becomes too dry, water may be added freely without any detrimental effects. Bechdel (31) stated in 1923 that roughages composed of clover silage and hay were decidedly better for milk production than hay alone as the sole roughage.

Atkeson and Anderson (20) compared sweet clover silage with corn silage. The sweet clover was cut with a binder and allowed to remain in the field a few hours before being placed in the silo. Eight milking cows were divided into two groups of four cows each. The double reversal system of feeding was used. Each period lasted 20 days. The results indicated that sweet clover silage was practically equal to corn silage for milking cows but that it was not as palatable as corn silage.

Dairy cows when dry can be wintered on legume silage alone (94). Sweet clover cut for silage when it was three and one-half feet high and just coming to bloom contained about 60 per cent water. Corn silage from the previous year was blown into the silo at the rate of one part of corn silage to 20 parts of sweet clover silage. The resulting silage was dark green in color and had a pungent odor which lessened as the silage aged. This silage kept satisfactorily with little spoilage. Four cows, two milking and two dry, were fed this silage. Two cows received silage alone and the other two received in addition three pounds of oat straw daily for a period of 126 days. The cows did not seem to relish the silage, although when forced to eat it, one cow consumed up to 94 pounds daily. Two of the cows consumed an average of 60 pounds per day for 126 days. One cow refused it entirely after 30 days.

The addition of straw to the ration did not affect the amount of silage consumption. The cows lost on an average of 182 pounds in weight. Milk production of both cows dropped greatly.

Soybean silage kept well, had a pleasant odor and cows ate it readily (224). On the other hand Woll and Humphrey (533) found soybeans cut in two-inch lengths when the beans were full sized and firm, but the leaves and stems still green, made a rank, distasteful silage less palatable than corn silage. Three out of 21 cows refused it.

Soybeans containing 30 to 40 per cent dry matter when put in the silo kept well and the loss in feeding value was no more than in case of corn silage (110). The silage required only 40 per cent the storage space required by hay.

Becker and co-workers (38) found that silage of good quality could be produced even when the green soybeans contained as little as 25 per cent dry matter. Putrefactive odors were apparent in the surface spoilage only. Soybean silage was less palatable than corn silage of equal quality. No flavor or odor characteristic of soybean silage could be detected in the milk. More protein and less total digestible nutrients were produced per acre with soybeans than with corn when used as a silage crop.

The addition of one per cent by weight of blackstrap molasses, diluted with an equal weight of water at the cutter, made good soybean silage (121). The soybeans were cut in the early bloom stage with a dry matter content of only 21 per cent. This silage contained 1.22 per cent lactic acid. Large quantities were fed to milking cows with practically no refusal. No objectionable flavors or odors were imparted to the milk of cows receiving soybean silage, even when fed immediately before milking.

Recent Experiments with Grass and Legume Silage.—Although the early work with legume silage indicated the possibility of conserving such a crop in the silo, no great attention was given to this important subject until recent years.

Watson and Ferguson (508) put green grass in a tower silo and compared the resultant silage with artificially dried grass. The silage was palatable and highly nutritious. In later investigations (509) where high protein, artificially dried grass, molasses silage and A. I. V. silage were compared for milk production, all three were highly digestible. There were no significant differences in milk yields, butterfat yields, butterfat percentages, and body weights of the cows due to feeding artificially dried grass, molasses grass silage and A. I. V. grass silage. The carotene content of molasses and A. I. V. grass silage was 49.8 and 57.1 micrograms per gram of dry matter respectively. Both were higher in this respect than artificially dried grass.

Bender and associates (43) reported that low-moisture silage reached a high temperature and much of it spoiled. Chopped silage was superior to long silage in palatability as tested with dairy cows, permitted much more

to be stored in the same space and reduced the loss of dry matter (558). Fresh, green grass, either alone or mixed with legumes, when chopped and placed in the silo with no other treatment, made a silage which was highly palatable. The losses of dry matter and carotene were low. Partial drying before chopping facilitated handling, increased the quantity of dry matter that could be stored in a given space, increased the surface spoilage, increased the temperature of fermentation to as much as 120° F., and in most cases made the silage more appetizing. Immature grasses made a more palatable silage than mature grasses. Cows ate good grass silage in about the same quantities that they would graze the grass from which the silage was made.

First cutting alfalfa was dried in the field to a dry matter content ranging from 42 to 73 per cent and successfully preserved in a silo. The total dry matter loss through spoilage on top and through fermentation was estimated to be 7.5 per cent. The carotene content averaged 64 micrograms per gram of dry matter when the crop was put in the silo and 48 micrograms per gram when it was removed. A feeding experiment with milking cows indicated that the alfalfa silage was equal if not superior to U. S. grade No. 2 alfalfa hay (170).

Methods of Filling the Silo.—The method of filling the silo is important (510). Warm fermentation process is achieved by relatively loose packing. Under the best conditions the temperature does not exceed 120° F. Losses, particularly of carbohydrates, must be high. The so-called cold process aims to keep the temperature at or below 80° F., and this end is achieved by cutting the grass in one-half inch lengths in order to facilitate packing, heavy tramping, and the application of pressure to the silo. At Jealott's Hill the best results have been obtained by allowing the mass to rise to a temperature of between 80° and 100° F. The silo is filled in layers, each of which is allowed to heat to this temperature, and finally sealed off with a layer of soil and small movable concrete weights.

Graves (169) reported the results of putting two cuttings of pasture grass in a silo. The first cutting was rather dry and mature and for these reasons water was added at the time of filling. This silage was unpalatable and apparently had undergone undesirable fermentation. The less mature and unwatered second cutting made excellent silage. The following year pasture grass at different stages of maturity were successfully ensiled without any supplement. Pasture grass as well as oats and peas have been preserved successfully in both tower silos and dirt covered stacks (230).

The size of the silo may be an important factor in determining the changes which take place in the silage mass. Experimental work with small containers or with silos with a capacity of 150 tons or more does not give results which can be applied in all cases to the average farm silo of 50 to 100 tons. For instance, there does not appear to be very much difference in the capacity

of an average farm silo for corn and alfalfa, while in the case of large silos, the capacity is greater for grasses and legumes than for corn.

The statement is often made that the hay crop can be placed in the silo regardless of weather conditions or the amount of water in the crop. Again this statement may hold for the large silo which is not water proof and where high pressures result in sufficient leakage to reduce the silage to the proper moisture content. If such a silo had no drainage then the quality of the silage made from high moisture material might be low. In case of an average farm silo of 50- to 100-ton capacity the pressure is insufficient to reduce high moisture forage to the desirable moisture content and butyric acid silage may result regardless of drainage facilities.

In filling the silo, the moisture content of the crop, the length of cut and the expulsion of air appear to be important points to consider. The warm process does not appear to be adapted to conditions in the United States since the time required to fill a silo is too great.

Acidity in the Silo.—Allen and Harrison (2) stated that to produce the best type of silage, it is essential that a rapid lactic acid fermentation take place. The acidity thus formed in the mass will prevent the onset of less desirable fermentations such as the butyric acid type. According to Virtanen (485) the development of butyric acid depends on the pH of the mass. Very little of this fatty acid was produced below a pH of 4.2. These results were substantiated by other workers (387, 287, 274).

Watson and Ferguson (510) stated that the ordinary process of silage making did not succeed in controlling the formation of butyric acid, and the amount increased rapidly with the pH, reaching a high level between pH 4.5 and 5.0. The A. I. V. process or the addition of molasses prevented the development of butyric acid. Molasses was somewhat superior to the A. I. V. method in this respect. There was very little butyric acid produced below a pH of 4.2.

The volatile bases produced in silage are also related to the pH. In case of ordinary silage with a pH of 4.91, the volatile bases made up 3.42 per cent of the dry matter, while molasses silage with a pH of 4.19, only 1.67 per cent of the dry matter consisted of volatile bases. A. I. V. silage with a pH of 3.82 had only 1.15 per cent of the dry matter as volatile bases (510).

The relation of the acidity of silage to the production of ammonia has been studied by several investigators (387, 98, 6, 538, 507). It is only when the pH rises above 4.5 that ammonia becomes very high.

The pH value of the silage is the most valuable criterion but it must be reinforced by a determination of the amount of volatile bases and volatile acids (507). When the water content of the silage is 80 per cent, the pH value is high and the butyric acid content is also very high, which is an indication of anaerobic fermentation. The feeding of silage high in butyric acid resulted in ketonuria (51).

Most investigators emphasize the importance of a pH of 4.2 or below for good silage making but excellent alfalfa silage has been produced without any treatment when the pH ranged from 4.61 to 4.78 (170).

Although the buffer capacity of plant material probably plays an important role in making silage from legumes, little attention has been devoted to this subject. In the making of A. I. V. silage allowance is made for the greater buffer capacity of legumes in the application of acids. The neutralizing power of forage crops for organic and mineral acids was investigated by Wilson (526). More acid was required to bring about a change of one pH in leguminous materials than was required by non-leguminous materials. Also, more acid was required to bring about a change of one unit in the region of pH 4.0 than in the region of pH 6.5. The quality of legume silage may be due in part to a variation in the buffer capacity.

Inoculation in Silage Preservation.—The quality of silage depends on the type of fermentation as well as the rate. Green material has been inoculated with various acid-producing organisms. The results of several investigators indicate that lactic acid cultures increased the acidity of the silage, facilitated the fermentation process and improved the quality of the silage (405, 564, 168, 330, 404, 481, 359, 144). Reid (404) using small containers reported that cultures of *Bacillus bulgaricus* organisms were capable of high lactic acid production which kept down the production of acetic and butyric acids. The improved quality of silage resulting from inoculation together with the addition of molasses may have been due to the molasses and not to inoculation. Also, Allen and co-workers (3) found that the losses of starch equivalents in silages made with a solution of dried whey, a solution of dried whey plus culture, and molasses plus culture were 15.3, 17.3, and 3.4 per cent respectively. On the other hand several investigators reported that inoculation did not affect the quality of the silage (159, 507).

The inoculation of ensiled material does not appear to be warranted in view of the limited experimental work which has been reported along this line.

Use of Inorganic Acids.—Various inorganic acids have been added to green plant material in order to stop respiration and control bacterial action. The most widely used is a mixture of hydrochloric and sulphuric acids known as the A. I. V. method which Virtanen (487) has recently described. Inorganic acids in addition to controlling respiration, also control two harmful processes which play a decisive role in the ensiled fresh forage; namely (a) protein breakdown, especially the cleavage of the amino-group from amino acids in the form of ammonia; and (b) fermentation caused by bacteria of the coli-group and by butyric acid bacilli. The reduction of the forage mass below a pH of four prevented the changes which produce abnormal silage. If the silage mass is too high in water, the pH rises during storage to a point where the detrimental breakdown processes immediately

set in. Good drainage prevents this decrease in acidity with storage. Virtanen stated that in one experiment, the pH of the artificially acidified silage with good drainage only changed from 3.65 to 3.48 during a storage period of one year. In a corresponding silage, without drainage facilities, the pH rose from its initial value of 3.4 to 5.2.

The A. I. V. method is favored by Virtanen over the sugar or molasses method, due to the fact that considerable loss of nutrients takes place during the first week before sufficient lactic acid is produced to lower the pH below four. The loss of dry matter by this method ranged from 5 to 10 per cent which is very low compared to the losses in haymaking.

Peterson and associates (381) studied the changes in A. I. V. silage made from alfalfa and soybeans. There was no appreciable loss of carotene. The determination of volatile and lactic acid showed that some fermentation took place in spite of the low pH of the silage. No notable changes in the level of milk production resulted from the feeding of the A. I. V. silage. Spectroscopic analyses of the butterfat for carotene and vitamin A were made. During the control period the butterfat contained 4.2 micrograms of carotene per gram and during the A. I. V. period the butterfat contained 6.8 micrograms per gram. Vitamin A rose from 4.0 micrograms per gram of butterfat during the control period to 9.0 in the A. I. V. period. The carotene content of blood plasma paralleled that in the butterfat. The cost of acid per ton of silage ranged from 62.5 to 92.7 cents. Peterson and co-workers also found that alfalfa silage made by the A. I. V. method had considerable more amino, soluble, and ammonia nitrogen.

Various other mixtures of inorganic acids have been used. The Defu process makes use of a mixture of hydrochloric and phosphoric acid. Penthesta is phosphorus pentachloride, a solid which in solution gives phosphoric and hydrochloric acids.

Fagan and Ashton (131) observed that the dry matter losses in grass silage made without treatment, by the A. I. V. method, by the addition of molasses, and by the Defu method were 28.9, 15.5, 9.4 and 9.6 per cent respectively. The loss in haymaking the same year under ideal conditions was 10 per cent of the dry matter in the field and 16 per cent loss during storage or a total loss of 26 per cent. These workers concluded that when the chemical composition, loss of dry matter and palatability of the silage are taken into consideration, the molasses method appeared to be the best suited for preserving grass.

The advantages claimed for the use of phosphoric acid are: (a) helps preserve the forage, (b) increases the phosphorus intake of the animal, and (c) adds phosphorus to the soil (64). A good grade of acid should be used in order to guard against a material high in fluorine. More experiments are needed with this method before it can be evaluated.

Molasses as a Preservative.—Since legumes and some of the grasses are

lower in soluble carbohydrates than corn and the cereal grasses (527), molasses or some other source of fermentable carbohydrate is believed to be needed for their successful conservation in the silo.

Several investigators have reported good results with grass and legume silages prepared with molasses (400, 459, 95, 68, 121, 509, 387).

Camburn and associates (64) ensiled immature and unwilted alfalfa with a dry matter content of 24 per cent. This silage was low in acid and exhibited an offensive putrefactive odor. The loss of nutrients was high. The addition of two per cent molasses to this material failed to make a good silage, but four per cent molasses resulted in a fair silage. Alfalfa cut at the same stage, ensiled after being wilted for two hours in the sun to a dry matter content of 34 to 38 per cent made good silage, however, the addition of two to four per cent molasses improved the aroma.

Alfalfa cut in one-half bloom containing 31 to 33 per cent dry matter, when ensiled green without molasses, made a satisfactory silage with a pleasing low acid aroma (64). The addition of two to four per cent molasses made a very good silage. Alfalfa ensiled with 34 to 42 per cent dry matter, without molasses, made an acceptable silage low in acid An acceptable silage was made from immature timothy before bloom which contained 24 to 27 per cent dry matter. The quality was improved, however, by the addition of one or two per cent molasses. Timothy in full bloom, containing 36 to 39 per cent dry matter when ensiled, resulted in a very satisfactory silage with or without molasses.

Woodward and Shepherd (558) reported the production of excellent silage with alfalfa alone. They emphasized the necessity of fine cutting and an optimum dry matter content. Perkins and associates (376) stated that it has long been known that a good grade of silage can be made from legumes alone. It has been shown repeatedly by experiment that the quality of the silage made by this method is greatly improved by partial drying. The dry matter content must not be so high that the material fails to pack well, because the air must be largely excluded to prevent excessive fermentation and decay. When these requirements were met the Ohio workers were unable to recognize any difference in the quality between silage made without treatment and that made by the addition of various amounts of molasses.

When large amounts of sugar are present in plant materials or added as preservatives to the crops to be ensiled, the fate of the sugars depends upon the conditions in the silo. Wright and Shaw (560) studied the sugar content of corn and sunflowers at the time of ensiling and of the resultant silage. When immature corn containing about 20 per cent total sugar on the dry basis was ensiled, only a trace of the sugar was found in the silage. Corn at the usual silage stage which contained about 12 per cent sugar on the dry basis produced a silage containing more than two per cent total sugars. These results were probably due to a marked difference in moisture content

between the immature and mature corn. Fraps reported from 1.87 to 2.39 per cent of total sugars on a dry basis for corn silage (145). In case of legume silage, fermentable carbohydrates would probably not be present except when excessive amounts are added as a preservative.

It is apparent from the literature that good grass and legume silage can be made without the addition of a preservative providing conditions are optimal, dry matter about 30 per cent, and cut in one-fourth to one-half inch lengths and well packed. Most authorities are of the opinion that the use of 40 to 70 pounds of molasses per ton allowed more leeway in putting up grass and legume silage. This may be advantageous under farm conditions. The use of molasses, however, does not insure good silage. Too high moisture content or too much trapped air in silage of low moisture content will result in poor silage regardless of the supplement.

The ensiling of grass and legumes in regions where good haymaking is prohibitive, because of bad weather conditions, appears to be a desirable practice. When such crops are properly ensiled, the loss of nutrients is less than when hay is made. This is especially true of carotene and dry matter. The necessity of using machinery built for such crops should be stressed. The labor required to produce an acre of grass and legumes appears to be less than in the case of corn. Also, the cost of producing 100 pounds of total digestible nutrients in pasture and in various hay crops was less than in the case of cereal grains or corn silage (556). The yield of total digestible nutrients per acre for a 14-year average in Wisconsin was about the same for alfalfa and corn silage (1).

NUTRITIVE VALUE OF THE PROTEIN IN ROUGHAGES

The factors affecting the protein content of roughages have been discussed. The nutritive value of protein depends on the essential amino acid content. Rose (414, 415) has listed the following essential amino acids and their requirement for growth when the non-essential amino acids are included in the food: lysine, tryptophane, histidine, phenylalanine, leucine, isoleucine, threonine, methionine, valine and arginine. Arginine can be partially synthesized by the animal.

Mitchell and Hamilton (339) summarized the results of the early investigators who studied the amino acid content of plant material. Several investigators determined the arginine, histidine, lysine, and cystine content of the protein of alfalfa hay, cocksfoot, corn, spinach, and runner bean (70, 336, 333, 334). The distribution of nitrogen in the various proteins from legume plants is shown in Table 17 (93).

These results indicate that the essential amino acids, such as arginine, histidine, and lysine are present in plant protein in liberal amounts. Tryptophane in the red clover plant varied during growth (485). The tryptophane increased to a high value when the plant was 35 centimeters in

TABLE 17

Nitrogen distribution in leguminous plants

	Alfalfa	Crimson clover	Red clover	Sainfoin	Vetch
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Amid N.	7.70	8.78	6.11	5.55	5.63
Humin N.	6.71	8.38	7.53	6.90	4.95
Arginine N.	18.16	17.29	13.36	12.12	14.88
Histidine N.	7.15	7.87	14.39	12.50	3.96
Lysine N.	5.44	4.49	3.15	9.55	9.56
Cystine N.	1.30	1.17	0.81	0.72	0.84

length. The tryptophane nitrogen made up 2.5 per cent of the total nitrogen but the amount gradually decreased as the plant matured. Virtanen (485) showed that the amino acids of growing plant proteins vary because the growing plant protein has no fixed composition.

Since Rose (414) showed that methionine rather than cystine was an essential sulphur containing amino acid, the amount of methionine in plant proteins is of great importance. Bailey (22) reported that the protein of cocksfoot grass contains 1.7 per cent methionine which accounted for 35 per cent of the total sulphur present.

The total sulphur, inorganic sulphur and organic sulphur of pasture grass cut at different intervals throughout the season showed a decrease with maturity (129). Since 90 per cent of the organic sulphur usually exists as cystine and methionine, it is likely that these amino acids decrease with the maturity of the plants.

Pollard and Chibnall (392) reported that grass proteins contain from 0.3 to 0.95 per cent cystine and that alfalfa leaf protein contained 1.2 per cent cystine. The possibility of a cystine deficiency in roughages was indicated by the work of Haag (189) with rats. Rats fed alfalfa leaf meal as the only source of protein responded to the addition of cystine. Low milk production of cows on a ration of alfalfa alone was believed to have been due to a cystine deficiency (190, 191). Kellermann (265) reported that young rats fed alfalfa as the only source of protein suffered from a deficiency which was immediately relieved by the addition of 0.1 per cent of l-cystine. The nutritive value of alfalfa protein was not enhanced by incubating with "ruminal juice" of sheep. The results of Pollard and Chibnall (392) and Crampton and Finlayson (81) indicate that cystine is not a limiting factor in roughage protein. Lugg (301) reported that plant protein contains 1.1 to 1.7 per cent cystine and 1.2 to 1.6 per cent methionine of the total protein nitrogen. The possibility of an animal deriving cystine from methionine and methionine from cystine was recently reviewed by Toennies (469).

Biological Values of Roughage Protein.—The limited data relative to the amino acid requirement of cattle and the amino acid content of feeds, make it imperative to use biological values as an index of the completeness

of proteins for growth and milk production. Nevens (357) obtained a biological value of 62 for alfalfa using rats fed at a 10 per cent protein level. His results also failed to show a supplementary effect of the corn grain proteins with alfalfa proteins. Similar results were secured by Smutts and Malan (442).

Sotola (445) studied the biological value of the protein in the whole hay, stems, and the leaves of first, second and third cuttings of alfalfa hay using lambs. The levels of protein intake for the stems, whole hay, and leaves were approximately 8, 13, and 18.5 per cent respectively. The average biological values of the proteins from the three cuttings were as follows: stems, 64; whole hay, 51; and leaves, 41. The variations in values are attributed to the difference in the levels of protein intake. Sotola (444) also studied the biological values of corn silage and sunflower silage and a combination of alfalfa and corn silage. The resulting biological values were: corn silage, 94; sunflower silage, 67; and a combination of alfalfa and corn silage, 81. These high values were probably due to the low protein content of the rations.

Morris and co-workers (349) investigated the biological value of various proteins for milk production. The biological values for fresh and dried spring grass were 75 to 80, and for fresh and dried autumn grass 60 to 65. These investigators believed that lysine was a limiting factor in milk production. Bartlett (25), however, was unable to substantiate the possibility of lysine being a limiting factor in milk producton of dairy cattle.

Turk and associates (475) working with sheep found that the biological values of proteins for maintenance and growth when fed at a 10 per cent level were as follows: clover protein, 81; alfalfa protein, 78. In an experiment with three lambs, alfalfa hay fed with no additional starch and sugar gave an average value of 50, whereas with starch and sugar added the biological value was 72.

Protein Synthesis in the Rumen.—The hypothesis that bacteria in the rumen synthesize amino acids from non-protein nitrogen was advanced many years ago. Armsby (13) in 1911 reviewed the early work on this problem. The opinion as a result of the earlier work indicated that certain non-protein nitrogen compounds may be used by the ruminant for protein synthesis in the rumen.

More recently Morris (348) and Krebs (285) have reviewed the literature on this subject. Morris pointed out that non-protein nitrogen is often added to a ration already containing more than the requisite amount of protein of good quality.

Woodman and Evans (544) were unable to show that bacteria from the rumen could synthesize cystine. Kotake (282) reported that certain bacteria are able to synthesize tryptophane while others cannot. Ehrenberg and Prittwitz (115) observed a 15 per cent decrease in milk production when 100

grams of ammonium carbonate replaced 500 grams of a mixture of soybean, peanut and cottonseed cake. Similar results were reported by Richter (407) when urea replaced some of the protein concentrate. Richter and Herbst (408) substituted glycocoll or urea for 50 per cent of the crude protein in a basal ration of milking cows. There was a drop in milk production and body weight. The decrease in milk production was less in case of glycocoll.

Recently Hart and associates (194) studied the effect of supplementing a low protein ration containing yellow corn, 30; starch, 20; timothy, 47; steamed bone meal, 2; iodized salt, 1; and cod liver oil, 0.5 per cent with ammonium carbonate, urea and casein. The gain over 14 weeks for the lot of calves on the low protein ration was 65 pounds; low protein ration plus ammonium bicarbonate, 105 pounds; with urea, 110 pounds; and with casein, 126 pounds. The results were explained on the basis of protein synthesis by bacteria in the rumen. Similar results were reported by Bartlett and Cotton (26).

The roughages appear to furnish protein of a high biological value for growth and milk production providing the quantity of protein is sufficient. These high biological values are due to the essential amino acids furnished by these proteins. The possibility of protein synthesis in the rumen is indicated although proof that the microorganisms actually synthesize the essential amino acids is lacking.

The non-protein nitrogen constituents of pasture herbage may bring about abnormal conditions in grazing animals. Greenhill (176) observed that pasture grass which caused serious disturbance among grazing stock was much higher in non-protein nitrogen than pasture grass from pastures where cattle were normal. Seventeen per cent of the nitrogen in normal pastures was non-protein nitrogen, while the grass from pastures in cases where cattle were sick contained 62 per cent of the total nitrogen as non-protein nitrogen.

FAT IN ROUGHAGE AND ITS NUTRITIONAL SIGNIFICANCE

The ether extract of feed is usually considered as being a good index to the fat content. This method of evaluating the true fats of roughages has not been universally accepted. Fraps and Rather (152, 153) and Rather (399) reviewed some of the earlier attempts to separate the fat from the non-fatty substances in the ether extract of plant materials. Rather reported that 68 per cent of the ether extract of roughage was non-fats. In other words, only 32 per cent of the ether extract was true fat. Chibnall and Channon (69) showed that only 27 per cent of the ether extract of leaf protoplasm consists of fatty acids. Recently, Horwitt and associates (240) showed that more than 55 per cent of the ether extract of spinach was non-fat in nature because most of the ether extract consisted of chlorophyll and waxes. Schulze (428) stated that in case of hay and coarse fodders, the

nutritive value of the ether extract must be considered low for it consists of wax-like substances and other constituents of doubtful value.

As a class, the roughages are low in ether extract and if only one-fourth to one-half were true fat, then most roughages appear to be very low in this constituent. The low digestibility of the ether extract of hays and fodders is probably due to the presence of waxes, chlorophyll and other substances not easily digested.

Unsaturated Fatty Acids in Roughage.—In view of the work of Burr and Burr (57), who showed that certain unsaturated fatty acids were essential to rats, the fatty acid composition of fats from roughages is of interest.

Smith and Chibnall (438) studied the fatty acid content of cocksfoot and perennial rye grass. The results are shown in Table 18.

TABLE 18

The fatty acid content of roughages

	Cocksfoot		Rye grass	
	Twitchell's method	Bertram's method	Twitchell's method	Bertram's method
	per cent	*per cent*	*per cent*	*per cent*
Saturated acids	11.1	15.2	11.9	16.8
Oleic	12.5	8.9	22.5	17.6
Linoleic	33.4	29.8	26.1	21.2
Linolenic	25.8	29.5	39.5	44.4

Speer and associates (447) working with dried spinach which contained 0.8 per cent true fat reported that about five per cent of the true fat was solid and that 26 per cent was liquid. The liquid fat was made up, in part, of 12.7, 34.7, and 26.3 per cent of linolenic, linoleic and oleic acids respectively. The solid fat consisted chiefly of palmitic, stearic with about three per cent cerotic acid.

It is interesting to point out that the true fats in the limited number of roughages studied were rich in the unsaturated fatty acids, which probably precludes a fatty acid deficiency among cattle fed liberally on pasture and hay providing the true fat of roughages commonly used have a similar composition.

Necessity of Fat in the Ration for Milk and Fat Secretion.—Recent studies by Maynard and associates (311, 312) and Gibson and Huffman (163) have suggested that a certain minimum level of fat is needed in the ration of the lactating cow for optimum milk production. The work of Graves and associates (173) with alfalfa hay alone indicated that fat per se may not be a limiting factor in milk production on roughage alone. Recent work lends further support to this idea (245).

The effect of food fat on the butterfat percentage of milk has also been investigated. Most of these studies indicated that food fat did not influence the percentage of fat in milk. Recently, however, several investigators have

demonstrated that cod liver oil feeding decreased the test (378, 166) while other oils increased the test of the milk (4, 161, 163) for a brief period. Powell (394) concluded from his experiments that the per cent of fat in the milk may be lowered considerably by changing from whole hay to hay and grain in pellet form. The feeding of alfalfa alone resulted in tests slightly higher than normal according to Graves and associates (173).

The trend toward greater roughage utilization and the use of low fat concentrates suggests a need for more information regarding the role of fat in milk and fat production.

CARBOHYDRATES IN ROUGHAGES AND THEIR NUTRITIVE VALUE

The carbohydrate fraction of feeding stuffs contains a wide variety of substances; the structural parts such as cellulose, lignin and pectin, and other constituents such as starch, fructosans, pentosans, and various sugars. Since the carbohydrate fraction represents about 75 per cent of the dry matter of the plant, their importance in the nutrition of cattle is apparent.

In the young growing plant, the tissues consist of cells largely filled with protein substances and cell walls made up of protein and cellulose. The adjacent cells are cemented together with pectins and the so-called hemicellulose material. As the cells mature, the protein of the cell walls disappear and is replaced by a deposit of hemicellulose and later by lignin.

Strepkov (453) has recently separated the carbohydrate complex into seven groups as follows:

1. Hot alcohol-soluble (sugar).
2. Cold water-soluble, but alcohol insoluble (dextrins, gums, pectins, B-amylan).
3. Soluble in water at 45°–47° C. (inulin).
4. Hydrolized by diastase (starch and glycogen).
5. Soluble in hot water (protopectin, zylan and araban).
6. Hydrolyzed by 2.5 per cent H_2SO_4 (galacten, mannan, pentosan).
7. Not hydrolyzed by dilute H_2SO_4 (lignin, cellulose and manno-cellulose).

Nitrogen-Free Extractives of Roughages.—The nitrogen-free extractives of feeds are estimated by subtracting the sum of the percentages of moisture, ash, protein, ether extract and crude fiber from 100. The constituents of this fraction of roughages have received little attention from the standpoint of chemical analyses and nutritive value. Some of the early investigations were made by Frear on timothy hay (157) and by Headden (211) on various Colorado feeds. Fraps (145) in 1900 reported the sugar content of the various feeding stuffs as indicated in Table 19.

The starch content of roughages was also studied (147). Alfalfa hay, corn silage, prairie hay, and Sudan grass hay contained 1.9, 6.0, 2.1 and 2.2 per cent starch respectively on a dry basis.

TABLE 19

The sugar content of various feeding stuffs

	Reducing sugars	Sucrose	N. F. E.	Total sugars	Total pentosans
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Alfafa hay	3.00	1.40	41.1	4.40	.....
Mixed hay	8.00	2.44	48.7	10.44	.....
Timothy	4.97	3.36	55.9	8.33	24.9
Crab grass	1.42	0.47	45.2	1.89	26.2
Green rape	4.14	2.97	44.4	7.72	9.6
Corn silage	2.01	0.11	53.0	2.13	.....

Guanzon and Sandstrom (181) recently studied the composition of the residual nitrogen-free extract fraction in nine feeding stuffs. Alfalfa hay with 40.4 per cent nitrogen-free extract contained 1.76 per cent reducing sugars, 1.65 per cent sucrose and 1.4 per cent starch.

The soluble carbohydrates in forage plants was studied by Wilson and Webb (527). Their data indicate that most of the legumes contain from four to six per cent soluble carbohydrates on the dry basis, while timothy, perennial rye grass and brome grass contain about eight per cent. The cereal grasses, barley, oats, rye, and wheat contain from 10 to 13 per cent and corn in milk about 20 per cent soluble carbohydrates.

In the corn plant sucrose is the characteristic carbohydrate of the vegetative portion (300). Most of this is stored in the stalk. The curing of corn in the field results in the loss of sugars, about the same loss that occurs in the silo. In the silo, however, the lactic acid formed from the sugar contributes to the nutrition of the animal.

The residual nitrogen-free extract of roughages may contain chlorophyll, organic acids and ligno-cellulose (147). Feeds known to be high in feeding value are characterized by a high content of sugars and starches, or if the starch content is not high, by a high protein content. The residual nitrogen-free extract is low in such feeds. On the other hand feeds which are known to be low in feeding value are generally characterized by high pentosans and residual nitrogen-free extract contents. Pentosans are usually low in concentrates and high in roughages while the reverse is true for starch.

According to Norman and Richardson (369) young rye grass is charac-

TABLE 20

Composition of nitrogen-free extract of feeds (181)

	Uronic acid anhydrides	Sugars and starch	Pentosans total	Residual nitrogen-free extract
	per cent	*per cent*	*per cent*	*per cent*
Alfalfa hay	25.76	12.01	25.51	62.50
Corn cobs	9.99	6.91	52.74	40.33
Timothy hay	10.60	12.08	28.90	58.99

terized by a high percentage of water-soluble material, only a small amount of which is nitrogenous. The major part was fructosan which decreased sharply as the grass matured. The free sugar consisted largely of fructose, although no particular significance has been attached to this finding because free fructose may be a result of the drying procedure. The dry matter of the young grass consisted of about 25 to 30 per cent fructose after hydrolysis while the hay varied from 14.6 per cent for that cut in June to 0.4 per cent for that cut in September. The leaves, stems and heads of the grass cut on June 2 contained 24.4, 35.4 and 17.3 per cent respectively of fructose after hydrolysis. Most of the fructose after hydrolysis was derived from fructosan since the grass contained only 1.64 per cent total reducing sugar expressed as fructose, of which 1.57 per cent was actually fructose.

The fructose, soluble protein and soluble ash constituents together did not account for all the cold water-soluble material. The presence of a glucose polysaccharide has been postulated. Cellulose, which continued to increase after the dry weight of the plant reached its maximum, may increase at the expense of stored fructosan.

Second growth rye grass was characterized by higher structural elements and lower amount of water-soluble constituents, such as fructosan, when compared with first cutting grass. This may account for the belief that autumn grass is not as satisfactory as spring grass for livestock even though the protein may be the same. Norman (368) stated that it is probable that the fructosans are of great nutritional importance because of their high availability.

A study of the carbohydrates in the wheat plant revealed a maximum sucrose content in the leaf on March 16; in the leaf sheath on June 8, and in the stem and head on July 5. Sugars fell rapidly with starch formation in the grain. Fructosans were present and were especially high in the young heads but fell rapidly as ear development and starch formation proceeded (23).

According to Norris and Resch (370) pectin, which is a constituent of young plant cells, is a complex mixture of substances having similar properties. It is probable that the usual sample of pectin consists of a central nucleus of galacturonic acid units to which arabinose and galactose units may be chemically attached in chains.

In a study of the nature and distribution of cell wall constituents, Buston (58) reported that fully grown cocksfoot grass contained 1.97 per cent pectin as calcium pectate. Hay made from the grass contained 1.95 per cent calcium pectate. The pectic substance in bean leaves varied from 6.5 to 8.9 per cent of the dry matter as calcium pectate. Norman found (367) that young rye grass contained 0.91 per cent pectate. The pectin content decreased with the maturity of the rye grass and when cut for hay it contained only 0.19 per cent. According to Norman, pectin is a cell wall constituent of the young plant cell which is replaced by cellulose and lignin at maturity.

The role of pectic substance in nutrition has been investigated by several workers. Recently Sullivan and Manville (455) showed that pectin and cellulose together with vitamin A are essential in the digestive tract for the synthesis of the enzyme lysozyme which aids in the control of the bacterial flora of the intestine.

The nutritive value of pectins in nutrition has received scant attention. Certainly more research should be devoted to this material in view of the possibility that the pectic substance along with easily fermentable cellulose may contribute to the succulence of young pasture grass.

Fraps (146, 147) also studied the coefficient of digestibility of the constituents of the nitrogen-free extract using sheep. The results for a few roughages are shown in Table 21.

TABLE 21

Coefficient of digestibility of constituents of N. F. E.

	Reducing sugars	Polysaccharoses	Starch	Pentosans in N. F. E.	Residual N. F. E.	Total pentosans	Pentosans in C. F.
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Alfalfa hay	97	98	86	56	69	53	41
Bermuda hay	97	99	90	44	48	44	43
Corn cobs	84	79	83	53	34	55	65
Corn silage (dry)	99	94	97	77	68	56	72
Kafir forage	94	97	95	43	42	54	46
Milo forage	81	79	60	57	41	62	68
Prairie hay	97	94	77	52	35	50	43
Sorghum hay	99	93	83	49	48	65	55
Sudan grass	99	84	77	53	38	55	58

The reducing sugars and sucrose of roughages were almost completely digested. The total pentosans in hays and fodders are generally digested to the extent of about 50 to 60 per cent. The digestibility of the pentosans of timothy hay cut in the early bloom stage ranged from 55 to 60 per cent. According to Fraps a pound of digestible nitrogen-free extract in hays and fodders is much less valuable to the animal than a pound digested from concentrates.

The soluble constituents of the nitrogen-free extract fraction of roughages are probably the most important parts from the standpoint of productive energy value. The losses due to respiration, fermentation and leaching of roughages may account for the marked variation observed in the nutritive value of roughages. The dissipation of the soluble carbohydrates of roughages may also account for the susceptibility of cattle to ketosis. This phase of the roughage question will be discussed in connection with the rumen digestion of cellulose.

Nutritive Value of Crude Fiber.—According to Armsby (14) crude fiber contains most of the cellulose, lignin and cutin, along with some of the more difficultly soluble hemicelluloses, particularly those containing pentosans.

Headden (210) studied the chemical composition of alfalfa in early bloom stage. He found that the crude fiber contained 79.0 per cent cellulose and 21.0 per cent lignin. The complete chemical composition of alfalfa-clover hay was given.

Norman (366) concluded that the crude fiber determination is misleading because the fraction obtained does not bear any definite relationship to the structural constituents of the material. The cellulose is partially attacked and the lignin is extensively removed. Highly lignified materials do not necessarily yield a crude fiber high in lignin. Crampton and Maynard (82) separated the crude fiber fraction into cellulose and lignin. They also concluded that the separation of crude fiber into its various components was highly significant from a nutritional point of view.

As has previously been stated, the cellulose and lignin content of plants increases with the rate of maturity. Williams and Olmsted (524) reported that alfalfa leaf meal contained 32.5 per cent cellulose and 1.5 per cent lignin. Norman (366) studied the composition of the crude fiber fraction in several feeds. The results are shown in Table 22.

TABLE 22

The composition of crude fiber on the basis of dry matter

Material	Crude fiber	Composition of crude fiber	
		Cellulose	Lignin
	per cent	*per cent*	*per cent*
Bean straw	45.8	76.8	18.6
Oat straw	35.2	92.0	6.8
Wheat plants	32.6	92.4	6.4
Hay	31.5	85.7	10.9
Vetches	31.1	74.3	20.2
Corn plants	22.6	96.5	3.5
Kale plants	17.3	76.2	18.1
Sugar beet pulp	14.5	87.9	10.6
Bran	11.3	93.0	2.1

About 97 per cent of the crude fiber fraction was made up of cellulose and lignin.

Williams and Olmsted (524) determined the cellulose and lignin content of alfalfa leaf meal and cabbage. Both were high in cellulose on a dry basis but alfalfa leaf meal contained 15.0 per cent lignin while cabbage contained only 2.6 per cent. Beet pulp and carrots were very low in lignin.

Kellner (268) in 1905 showed that if the incrusts in straw (silica and lignocellulose) were removed by treatment with alkaline reagents then the digestibility of the cellulose in the residual product was extremely high.

Ustyantzev (479) in 1906 observed that wheat straw, when fed to sheep, had a low nutritive value but that cellulose from the same straw freed from the incrusting substance was equal to isodynamic quantities of starch and sugar as protectors of protein and fat. Fingerling and associates (135) re-

ported that pigs were able to dissolve pure crude fiber as are ruminants but that they lose this ability as the incrustation or lignification of the fiber increases.

Woodman (536) demonstrated the relative digestibility of the fiber in young and mature plants as shown in Table 23.

TABLE 23

Digestion coefficients of constituents of grass in its young leafy stage of growth and at the hay stage of maturity

	Young leafy grass	Grass at hay stage of maturity
	per cent	*per cent*
Fiber	84.2	52.4
Carbohydrates	97.4	53.0
Protein	85.4	50.0
Fat	60.0	30.0

The digestibility of fiber, therefore, appears to be inversely proportional to its content of lignocellulose. Woodman also showed the difference in the digestibility of non-lignified and lignified feeding stuffs. Non-lignified feeds such as sugar beet pulp, mangolds, cabbage and sugar beet tops showed coefficients of digestibility of the cellulose as 89.7, 78.0, 74.0, and 71.6 per cent respectively. On the other hand, the coefficients of digestibility of the cellulose of such lignified feeds as oat straw, wheat straw, cottonseed meal, linseed meal and wheat bran were only 54.0, 50.0, 37.0, 32.0 and 26.0 per cent respectively.

Lignin occurs in mature plants chiefly as lignocellulose. As already indicated, lignin is believed to be responsible for the marked drop in digestibility of forage during development. Crampton (79, 80) using rabbits studied the effect of lignin on digestibility of cellulose. He observed that as the lignin increased the coefficients of digestibility of the dry matter decreased. These data support the work of Prjanischnikow and Tomme (397) in which they observed that after the treatment of rye straw with ClO_2, the digestibility of its fiber by rabbits increased from 15 to 79 per cent. This was probably due to the partial removal of the lignin.

The digestibility of lignin has been reviewed by Crampton and Maynard (82). The results from the available literature are conflicting. These workers studied the digestibility of lignin by rabbits and a steer. In the case of rabbits, 97.8 per cent of the food lignin was recovered in the feces, while 99.3 per cent was recovered in the case of the steer. It appears that lignin is almost biologically inert.

Crampton and Maynard (82) proposed a scheme of carbohydrate partition in feed analysis into lignin, cellulose, and other carbohydrates, which may have more biological significance and hence be of greater usefulness in predicting feeding values than the present division into crude fiber and

nitrogen-free extract. In the case of the steer the coefficient of digestibility of the nitrogen-free extract by the standard method was 67 while by the suggested scheme it was 92 per cent.

The separation of the crude fiber fraction into cellulose and lignin appears to be a step in the right direction. The old crude fiber method did not differentiate between non-lignified and lignified material and consequently failed to predict the nutritive value of the roughage.

Rumen Digestion.—The rumen digestion of roughage high in fiber has been studied by many investigators. Much of the earlier work was reviewed by Woodman (536). Recently Pochon (389, 390, 391) concluded that fatty acids were the principal end-products of rumen digestion and not glucose as had been postulated by Woodman (536). Woodman and Evans (546) has recently reported results which substantiate Pochon's findings. Pochon isolated an organism (*Pletridium cellulolyticum*) which is capable of digesting cellulose. This facultative anaerobe was isolated from the rumen of cattle and sheep. In the fermentation of filter paper with filtered rumen contents and $CaCO_3$ in an alkaline medium, the end products were formic acid, acetic acid and some propionic acid and ethyl alcohol but no reducing sugar. When the reaction of the medium was adjusted to a pH of 4.0–5.0, or when toluene was added, the cellulolytic activity was markedly reduced and glucose was the main end-product.

The pH of the saliva is 8.4 and aids in the neutralization of the end-products of fermentation (271). Monroe and Perkins (344) studied the pH of rumen content of cows fed on various rations eight hours after feeding. The pH was 7.0 when grain and hay were fed and the feeding of corn silage or A. I. V. silage did not change the pH of the rumen appreciably.

The importance of rumen digestion is not commonly appreciated. A large number of roughages consist of constituents which are not digested by enzymes elaborated by the animal organism but are broken down by micro-organisms in the rumen. Approximately 50 per cent of alfalfa is dependent upon rumen fermentation for its digestion. These constituents include cellulose, compound celluloses, pentosans, levulosans, galactans, mannans and pectic substances.

The observation made by early workers that a pound of digestible cellulose was equal in nutritive value to a pound of digestible starch points to the production of end-products of rumen fermentation which can be converted to net energy in the animal body. The *in vitro* experiments of Pochon, where a preponderance of the end-products were acetic acid, do not solve the problem since acetic acid is not regarded as a source of chemical energy but is changed to thermic energy, which would be of little value under most conditions of feeding.

Possible Relation of the Rumen to Ketosis.—Ketosis is a disease characterized by the inability of animals to completely burn fat. The incompletely

burned fatty fragments are called ketone bodies. Their accumulation in the body of cattle result in a drop in milk production, in a decrease in appetite, and in body weight in the more pronounced cases. A nervous type of ketosis has been observed occasionally. Ordinarily this condition is due to a lack of available soluble carbohydrates in the small intestine. Ruminants are more likely to develop ketosis than other classes of livestock. This may be due to the conversion of foods which stagnate in the rumen for an appreciable length of time, to fatty acids by the rumen flora. The soluble material has a greater chance of getting past the rumen without being acted on by bacteria and consequently is effective in the prevention and cure of ketosis. A certain type of rumen flora produced ketone bodies (279). Cattle are more likely to suffer from ketosis during the winter in sections where the roughage is low in soluble carbohydrates. As previously indicated, hay may lose soluble carbohydrates due to respiration, fermentation and leaching. The conservation of soluble carbohydrates in roughages for winter feeding is an important health and economic problem in dairy cattle nutrition.

ROUGHAGES AND MINERALS

Calcium.—As a general rule, roughage is a good source of calcium and a poor source of phosphorus as shown by the average analyses of feeds (350, 340).

In the early experiments dealing with the effects of low calcium rations, the roughages were probably low in carotene, consequently, reproductive failures and other symptoms which were attributed to a lack of calcium were due in fact to a carotene deficiency (199, 329). Early metabolism trials also indicated a great loss of calcium from the body of milking cows regardless of the calcium intake (139, 198, 323, 327). More recently, short-time balance trials in connection with long-time feeding experiments indicate that cattle utilize about 50 per cent of the calcium intake on low calcium rations (249, 87). Long-time metabolism trials (117, 118) also gave similar results. Cows on low calcium rations for a long time showed no ill effects (328, 373).

Becker and associates (39) observed broken hips and bones of low breaking strength among cows fed limited roughage. The calcium requirements for maintenance and milk production have not been definitely worked out. Mitchell (340) suggested 26.4 grams of calcium daily for a 1,200 pound cow producing 30 pounds of milk testing 3.5 per cent fat.

It is apparent from the literature that the liberal feeding of roughage containing about 0.30 per cent calcium on the dry basis furnishes an ample supply of this element for maintenance and liberal milk production.

The calcium requirement for growing calves appears to be very low when they are supplied with ample vitamin D. Theiler and co-workers (465) obtained fair growth in heifers fed a ration containing five grams of calcium

daily. Good growth and normal bone formation occurred in dairy heifers fed a ration containing 6 to 21 grams of calcium daily from birth to two years of age (243). The low calcium ration used by Lindsey and associates (298) contained too much calcium for critical interpretation. The rickets-like condition of young cattle observed in the field by Gullickson and co-workers (187) was associated with very heavy grain feeding and very light roughage feeding. The condition was attributed to an insufficient supply of vitamin D and calcium. Under normal conditions of liberal roughage feeding this condition is not observed.

The greater use of good roughages, especially legumes or mixtures containing legumes, assures an adequate supply of calcium for growth, reproduction and milk production.

Phosphorus.—Phosphorus deficiency occurs among cattle, especially milking cattle, in many localities throughout the world. This is shown in Table 24.

TABLE 24

Phosphorus and calcium content of roughages reported from various localities

Author	Geographic location	Crop	Insufficient		Sufficient	
			P	Ca	P	Ca
			per cent	*per cent*	*per cent*	*per cent*
Orr (372)	Scotland	Pasture	0.137	0.150	.....	.....
Stohmann, cited by Eckles et al (111)	Germany	Hay	0.092	0.450	0.188	0.645
Kellner, cited by Eckles et al (111)	Germany	Hay	0.113	0.593	0.188	0.678
Guthrie, cited by Eckles et al (111)	Australia	Hay	0.121	0.270	0.121	0.393
Henry, cited by Orr (372)	Australia	Pasture	0.121	0.273	0.245	0.296
Tuff (474)	Norway	Hay	0.070	0.257	0.191	0.628
Dircks, cited by Tuff (474)	Norway	Marsh hay	0.050	0.132	.....	.....
Aston (19)	New Zealand	Pasture	0.118	.....	.....	.....
			0.083	.....	.....	.....
			0.114	.....	.....	.....
Theiler et al (464)	South Africa	Pasture	0.107	.....	0.140–0.262	.....
Hart, et al (193)	Wisconsin	Sweet clover	0.098	.....	.....	.....
			0.143	.....	.....	.....
Scott (429)	Montana	Alfalfa	0.124	1.749	0.173	1.485
		Clover	0.131	1.642	0.147	1.142
		Wild grass	0.074	0.320	.....	.....
		Red top	.....	.....	0.146	0.264
		Bunch grass hay	.....	.....	0.142	0.221
Eckles, et al (113)	Minnesota phosphate deficiency area	Alfalfa	0.212	.....	.....	.....
		Timothy	0.106	.....	.....	.....
		Prairie hay	0.112	.....	.....	.....
Eckles (111)	Minnesota	Alfalfa	0.190	.....	0.257	.....
		Timothy	0.107	.....	0.135	.....
		Prairie hay	0.100	.....	0.108	.....

The symptoms of phosphorus deficiency in cattle were described by Theiler (464) as osteophagia (bone chewing), pica (craving for things not ordinarily classed as food), stiffness and anorexia. Anorexia is the principal deficiency symptom of severe phosphorus deficiency (248, 276). Under such conditions, bone and wood chewing do not occur until partial recovery has taken place. Pica or depraved appetite is not usually manifested by cattle when the blood plasma inorganic phosphorus is about one mgm. per cent.

Several investigators observed that a lack of phosphorus in the ration resulted in a decreased food utilization (464, 112, 111, 113, 409, 276). Forbes (138) failed to show a difference in growth or in the utilization of food energy or protein between rats fed low phosphorus and high phosphorus diets. The efficiency of food utilization in uncomplicated phosphorus deficiency in dairy cattle is difficult to measure, due to the development of anorexia.

The phosphorus requirement of dairy heifers from birth to first calving is about 6 to 12 grams per day (248). Archibald and Bennett (9) stated that heifers can make average growth on rations supplying 1.8 grams of phosphorus per 100 pounds of live weight during the first year of life, 1.7 grams during the second year, and 1.2 grams during the third year.

Uncomplicated reproductive failures were not attributed to a phosphorus deficiency but the disturbance in estrum and the low calf crop among cattle in phosphorus deficient areas, under natural conditions, was probably due to complicated nutritive deficiencies prevalent under such conditions (114).

The phosphorus requirement for lactation was determined by Huffman and associates (248, 289) from balance trials and a study of the relation of phosphorus intake to blood inorganic phosphorus. Milking cows require about 0.7 gram of phosphorus per pound of milk above maintenance when 10 grams of phosphorus is allowed per 1,000 pounds of live weight. Mitchell (340) suggested a lower requirement which may be satisfactory when roughages other than alfalfa are used or it may apply to cows which have had a high phosphorus ration for years. In the experiment reported by Huffman and associates, the cows were raised on a low phosphorus ration from early age.

Calcium-Phosphorus Ratio.—The Ca/P ratio apparently has very little effect on the efficiency of calcium and phosphorus utilization in case of dairy cattle. Ratios from 1 : 4 to 10 : 1 have not interfered with calcium and phosphorus utilization (243) (191). An extreme ratio of about 20 : 1 appeared to depress phosphorus utilization (113). Theiler and associates (463) stated that the decreased food consumption of phosphorus deficient animals was not wholly due to inadequacy of the phosphorus but was also associated with the calcium content of the ration. Marek and associates (305), concluded that osteomalacia in cattle may be due to the feeding of rations too high in calcium and magnesium.

The trend toward greater utilization of roughages through pasture, silage and hay tends to accentuate a phosphorus deficiency. As a rule, roughages are low in phosphorus and grains are medium to high in this element. When appetizing roughages which are high in protein are fed, high producing cows may not receive sufficient phosphorus. When roughage containing 0.2 per cent phosphorus or less is fed a phosphorus supplement low in fluorine should be supplied in order to insure a good appetite for roughage. Usually a mixture of odorless steamed bone meal and salt equal parts, fed ad. lib. is a satisfactory supplement.

Iodine.—The iodine content of roughages depends on the iodine content of the soil (320). The iodine content of corn grown on soil to which increasing amounts of potassium iodide were added during the growing season showed a marked increase. The iodine content of roughages varies markedly as indicated in Table 25.

In sections where the soil is low in iodine the plants may be low in this element. The data included in Table 25 for spinach from various states are given to illustrate this point.

The water supply also contributes iodine to the animal. When the foods and water are low in this element "big neck" or goiter occurs among new-born calves. The iodine requirement for reproduction is 400 to 800 micrograms per 1,000 pounds of live weight (340). On farms where goiter occurs among new-born calves iodine should be added to the ration preferably as iodized salt. There is no indication that an iodine supplement is advantageous under other conditions. Regarding the relative merits of organic and inorganic iodine, the statement that "iodine is iodine" seems approprate.

Manganese.—The manganese requirement of cattle is not known. The amount of this element in roughages depends on the reaction of the soil as well as the amount present (423). As a general rule, the grasses are relatively good sources of manganese. Alfalfa was found to vary from 11 to 63 milligrams per kilogram but the stage of maturity was not a factor. Oat hay was found to vary from 25 to 280 milligrams per kilogram depending on the acidity of the soil. Roughages grown on acid soil were higher in manganese than those grown on alkaline soil. Other roughage varied in manganese in a similar manner.

Recently Blakemore and associates (48) attributed grass tetany in cattle to an excess of manganese in the pasture grass. Pastures where this disease occurred were much higher in this element than were healthy pastures. The feeding of manganese salts at rather high levels depressed blood magnesium in animals. This work has not been confirmed by other workers.

Iron, Copper and Cobalt.—Nutritional anemia among cattle and sheep has been observed in certain widely scattered areas of the world. This condition has been called "bush sickness," "skinnies," or "Morton Mains ailment" in New Zealand; "daising," "pining" or "vanquish" in Scotland;

"lecksucht" in Holland; "Nakuruitis" in Kenya Colony, East Africa; "coast disease" in King Island, Tasmania; "salt sick" in Florida and "neck ail" in Massachusetts. The literature on this problem has recently been reviewed by Neal and Ahmann (355) and Marston and associates (308).

TABLE 25

Iodine content of roughages

Feed	Micrograms per Kg.	Location
Pasture grass (165)	260–2020	Scotland—various parts
" "	2.3–170	England— " "
Alfalfa (424)*	560–5750	Germany
Red clover*	630–2000	"
Oat straw*	360–2050	"
Barley straw	950–28000	"
Grass (165)	153–5000	?
Hay	56–440	?
Grass hay (341)	34–448	South Carolina
Clover (crimson)	33–89	" "
red	218	" "
alsike	170	" "
white	33	" "
Alfalfa		
Peruvian	352	" "
Kansas	86	" "
Dakota	72	" "
Vetch		
Purple	504	" "
Monantha	302	" "
Hairy	504	" "
Woolsey pod	504	" "
Soybean	trace to 403	
Pasture grass		
Bermuda grass	100	" "
Lespedeza	150	" "
Johnson grass	350	" "
Pasture** (77)	190–450	Somerset, England
" ** (77)	130–500	Suffolk, England
Clover	190	Jealott's Hill, England
Cocksfoot	190	" " "
Yorkshire	390	" " "
Meadow Foxtail	270	" " "
Spinach (217)	694 (dry basis)	South Carolina
"	567 " "	Georgia
"	32 " "	California
"	19.5 " "	Oregon
"	226–1083	Oklahoma

* fertilized.
** survey.

The results of early investigations indicated an iron deficiency but iron supplements in certain localities failed to produce uniform results. In 1935, Marston (307), Underwood and Filmer (477), Grimmett and Shoreland (178) and Lines (299) demonstrated the value of cobalt as a supplement to pastures where this type of nutritional anemia occurred.

Hopkirk and Grimmett (238) reported that healthy pastures usually contained more than 0.07 parts per million of cobalt. McNaught (321) found that "bush-sick" pastures averaged less than 0.04 parts per million of cobalt while pastures from healthy areas averaged 0.11 parts per million but varied with the season. Askew and Maunsell (18) and Askew and Dixon (17) increased the cobalt content of herbage by the application of cobalt chloride.

Becker and Gaddum (37) and Neal and Ahmann (355) found that the use of iron and copper supplements aggravated the disease which was prevented or cured by cobalt. Workers in Australia (308) have reported that the treatment of "coast disease" with cobalt alone permitted growth in some animals but failed in most cases to prevent the progressive development of anemia. Treatment with copper and cobalt prevented the development of anemia. The administration of cobalt chloride and nickel was more effective than cobalt alone in the treatment of Morton Mains ailment (105).

Table 26 gives the copper content of forage crops reported by different investigators.

TABLE 26

Copper content of roughages on the dry matter basis

Forage	Copper	Forage	Copper
	mg. per Kg.		*mg. per Kg.*
Bluegrass (316)	7.5	Alfalfa hay (319)	10.0
Kentucky bluegrass (317)	7.5	Alsike clover	6.9
Alfalfa foliage	8.0	Bluegrass	14.0
Red clover foliage	8.0	Orchard grass	5.0
Kentucky bluegrass (318)	14.0	Red clover hay	17.0
Alfalfa hay (124)	9.1	Red top	4.0
1st cut. (Wis.)	4.5	Soybean	8.0
2nd cut. (Wis.)	14.8	Sweet clover	9.0
Colo. sample 1	6.9	Timothy hay	5.0
Colo. sample 2	11.9	Wheat straw	3.0
Bluegrass	8.3	Leeksuch area hay av. (437)	2.0–3.0
Oat straw	3.8	" one case	3.0–5.0
Red clover	17.6	" one case	1.0
Rye straw	4.4	Normal hay av.	6.0–12.0
Soybean hay	8.2	" " one case	5.0
Sweet clover hay	11.8	Normal grass or pasture	20.0–30.0
Timothy hay	2.2		
Vetch hay	9.6		
Wheat straw	2.1		

Archibald and associates (10) reported that nutritional anemia, called "neck ail" by the farmers, occurred in several localities in Massachusetts. These investigators concluded that the anemia was due to an insufficient amount of iron in the native forage. Spectacular recovery followed the administration of iron compounds to the affected animals. The addition of iron compounds to the soil from farms where the disease had occurred, resulted in a uniformly large increase in the percentage of iron in grasses grown on these soils.

A deficiency of iron, copper or cobalt or a combination of these elements is very unlikely to occur except in isolated areas. Most roughages are good sources of these blood-forming elements. Certainly, the general use of commercial supplements furnishing these elements is not warranted.

Other Minerals.—Magnesium is found abundantly in most roughages. Since the requirement for growth is only 8 to 10 milligrams of magnesium per pound of body weight, the possibility of a magnesium deficiency in the ration is indeed remote (247). The disturbed magnesium metabolism which occurs in grass tetany and milk fever is probably not associated with the magnesium content of the rations.

There is also very little likelihood of a potassium deficiency among cattle since this element is found in large quantities in most feeds, especially roughages. Lincoln (296), however, after analyzing 60 samples of pasture herbage in Mauritius, concluded that the pastures were deficient in nitrogen and potassium and that the phosphorus content was usually low.

Many feeds are low in sodium and chlorine because of the low sodium and chlorine content of the soil in many localities. Common salt supplies these elements. "Alkali disease" or selenium poisoning among cattle is due to the toxic effect of selenium in feeds (353). Fortunately the areas affected with this disease are not wide-spread. Ferguson and co-workers (134) reported that a large area of pasture in Somerset could not be grazed by cattle due to the toxic effects of molybdenum in the grass.

ROUGHAGE AND VITAMINS

Roughages as a Source of Carotene.—The plant synthesizes carotene, consequently, roughages as a carrier of this food constituent are of great importance. Virtanen (486) found that carotene was higher in the rapidly growing plant and reached a maximum value before or at the beginnig of flowering. He also observed that proper fertilization increased the carotene content while factors which retarded growth lowered the carotene content. The vitamin A content of young alfalfa (10–12 inches high) was much greater than that of alfalfa in the bloom stage (205). The vitamin potency of alfalfa is located chiefly in the leaves.

The carotene content of rye, Kentucky blue grass, red top, Dakota brome, orchard grass, big blue stem, Canadian brome, little blue stem and local brome grass was determined throughout the pasture season (21). All pasture grasses studied showed a relatively high carotene value in early summer, but with wide variations. The carotene content decreased markedly during the hot months of midsummer. After the fall rains, the carotene content increased with the exception of the big blue stem and Buffalo grass.

The vitamin A of grama range grass when cut in August showed marked potency. Approximately twice as much of the grass cut in September and 100 times as much cut in November was necessary to produce the same rate of gain in rats (441). Hay cut at the early bloom stage contained more

vitamin A, as a rule, than that cut at other stages of growth, the method of curing being the same (107).

Losses of Carotene during Roughage Conservation.—Although grasses and legumes are high in carotene when cut at the proper stage of development, the resulting field-cured hay is extremely variable in this respect. Russell (417) observed that leaves from plants dried by artificial heat contained seven times as much vitamin A as leaves from hay that were cured in the field. Hay exposed to the sun without exposure to dew or rain showed a loss of vitamin A.

The exposure of alfalfa hay to sun, rain or dew over a period of several days resulted in a marked loss of vitamin A (45). There was a 75 per cent loss of vitamin A when alfalfa was left in the field over night (440). Alfalfa bleached severely as a result of one week's exposure to sun and rain in the swath contained but four per cent as much vitamin A as the sample cured in the dark.

Fresh third cutting alfalfa hay cocked, cured and not sweated in a stack contained 308 rat units of vitamin A activity per gram (554). The same hay cured for three days in the swath and then cocked and sweated in the stack contained 116 rat units. The same hay cured one day in the swath and sweated in the stack contained 144 rat units. Sweating did not cause a very significant loss of vitamin A activity.

There was no loss of carotene when alfalfa was artificially dried but when air dried the loss was 67 to 88 per cent (425).

Russell and co-workers (418) showed that carotene disappears rapidly from freshly cut plant material. They observed a loss of 80 per cent of the carotene in alfalfa during the first 24 hours of drying in the field. Similar results were reported by Guilbert (182) and Vail and associate (480). Loss of the vitamin A occurred soon after cutting (107). Also, serious deterioration occurred when the hay was exposed to heavy rains, or to intermittent showers, followed by sunny weather. The damage was less when the hay was cocked than when it was cured in the swath. Hauge and Aitkenhead (207), Hauge (206), and Guilbert (182) presented evidence which indicated that the large loss of vitamin A potency during field curing of hay was due to enzyme action.

Dexter and Moore (100) determined the carotene content of alfalfa cured in the swath, windrow, and cock and found that there was no appreciable difference between the hay cured in the swath and windrow 10 hours after cutting but that the alfalfa cured in the windrow was higher in carotene from 19 to 120 hours after cutting. There was no advantage of cocked hay over that cured in the windrow in carotene content at the end of 72 hours. Similar results were reported by Bartlett and associates (27).

Fagan and Ashton (132) did not observe a decline in carotene in grass after wilting for 24 hours in the field and only a small decrease after 96 hours. The weather during this time was ideal.

It was found that partial field drying or wilting for prolonged periods under unfavorable climatic conditions may destroy as much as 66 per cent of the original carotene. Much larger amounts of carotene are lost when herbage is fully exposed to sunlight than when wilting takes place in the shade. Rain accentuates the loss of carotene after 24 hours.

Fraps and Kemmerer (149) reported that carotene in alfalfa meal was more stable when stored at 6° C. than it was when stored at room temperature. Carotene losses from alfalfa meal stored in pint or quart jars at room temperature varied from 8 to 70 per cent in eight weeks, while at refrigerator temperature the loss varied from 0 to 26 per cent. When alfalfa meal was packed in homeopathic vials at a temperature of 35° C., it lost carotene rapidly at first, then quite slowly, indicating that some of the carotene may be easily destroyed while a portion may be protected in such a way that it is much less easily destroyed.

Taylor and Russell (462) reported that chopped artificially dried alfalfa hay, stored in bags in a barn, lost 50 per cent of its carotene during the first three months of storage (late summer and early fall). There was no loss of carotene during the winter but a further loss of 25 per cent occurred during the succeeding summer season. Storage of ball-milled, artificially dried alfalfa hay in vacuo in the dark at 0°–5° C. preserved the carotene very efficiently for 20 months. Both the exclusion of air and a low temperature are important factors in carotene preservation. The degree of fineness was of little importance. Very little carotene is lost during dehydration providing the drying temperature is sufficiently high.

Alfalfa leaf meal lost 50 per cent of its vitamin A in 11 months (154). Miller and Bearse (337) observed some loss of vitamin A when dehydrated grass, dehydrated alfalfa and sun-cured alfalfa were stored for one year, the rate of loss being greater with the grass than with the alfalfa. Kane and associates (163) showed that the loss of carotene in hay varied with the storage temperature.

Although as a rule the estimation of the color of the hay is an evaluation in terms of carotene, however, hay may have the good color of U. S. grade No. 1 and yet may not be high in carotene because chlorophyll is more resistant to change than carotene. The hay grade, therefore, is only a rough index of its carotene content.

Silage.—The conservation of carotene in silage making has been discussed under the preservation of nutrients. In view of the great losses of carotene during the curing process (ordinary methods) and the loss in storage, the silo appears to be one possible method of solving this problem. There was no loss of carotene when alfalfa and soybean plants were ensiled by the A. I. V. method (381). Watson and Ferguson (509) gave the carotene content of molasses silage and A. I. V. silage, on the dry basis, as 49.8 and 57.1 milligrams per cent.

Timothy silage was found to contain more carotene on the dry basis than the best dehydrated alfalfa hay (42). The high carotene content is of importance in the production of winter milk with a high vitamin A and color content. Silage made from grass was just as high in carotene as the fresh grass (40).

According to Woodward and Shepherd (558) an outstanding characteristic of the silages as compared with the hays was their superior content of carotene. These investigators preserved the carotene in the fresh, green, untreated alfalfa and grasses which they ensiled. The outstanding result of this investigation was the high preservation of carotene in grass and legume silage made without any treatment. The addition of inorganic acids or molasses did not conserve the carotene any more effectively than no treatment. In the 1936 trial, first cutting alfalfa in the fresh state contained 164 micrograms of carotene per gram on the dry basis, while no treatment silage, acid silage, molasses silage and field cured hay contained 175, 168, 112, and 16 micrograms of carotene per gram of dry matter respectively. Other workers have also reported the carotene content of other grasses and hays (216, 173, 425).

TABLE 27

Carotene content of feeds (322, 529)

Feed	Water	Carotene per gram of dry matter		
		High	Low	Average
	per cent		*micrograms*	
Fresh green Kentucky bluegrass	68.4	620	424	522
Fresh green corn plant, cut for ensiling	78.1	115	70	92
Corn fodder, old and dry	9.1	6	2	4
Corn silage	73.7	60	13	39
Wheat straw	8.4	.....	.....	2
Clover hay, U. S. Grade No. 1	.....	43	11	23
Corn stover (dry)	.....	6	2	4
Dehydrated alfalfa leaf meal	.....	.....	.....	33.6
Cocksfoot (132)	.....	.....	.....	33.0

Carotene Requirement of Dairy Cattle.—Reproductive failures in cattle associated with the feeding of roughage of poor quality were formerly attributed either to a calcium deficiency or to the so-called injurious effects of cottonseed meal. In the early studies with low calcium rations, the roughages used were oat or wheat straw, cottonseed hulls or timothy hay of poor quality. The work of Reed and Huffman (402) showed that reproduction was normal when timothy of high quality, from the standpoint of greenness, was fed along with corn silage as a roughage. These results were substantiated by Hart and co-workers (195).

Cottonseed meal injury in cattle, which had been attributed to gossypol, was shown to be due to the lack of the factor present in good hay (403, 242). Blindness was observed among calves when wheat straw was fed as

the only roughage. This type of blindness was associated with a constriction of the optic nerve where it passed through the optic foramen (403, 347). Recently this type of blindness in calves was shown to be due to a vitamin A deficiency (346).

The relation of the quality of roughage to cottonseed meal injury in cattle has been studied extensively by Curtiss and associates and more recently reviewed by Curtiss (88). The relationship of the quality of roughage to cottonseed meal injury was also studied by Kuhlman and co-workers (286) and Cunningham and Addington (86).

Reproductive failures under natural conditions due to a deficiency of vitamin A in the roughage have been reported by Hart and Guilbert (200). Converse and Meigs (74) and Meigs and Converse (325) also associated the birth of weak and blind calves with the feeding of hay low in carotene.

Converse and Meigs (75) reported that when the ration contained more than 86 micrograms per pound of live weight, normal reproduction occurred, but when less than this amount was present, reproduction was not normal. On this basis, a 1,000 pound cow would require 86,000 micrograms of carotene daily. If such a cow consumed 20 pounds of hay containing 10 micrograms per gram, she would receive sufficient carotene to meet her requirements for reproduction. Since the average hay usually carries 15 to 20 micrograms of carotene per gram, there appears to be meager likelihood of reproductive failure occurring under farm conditions except in extreme cases. Also, cows receiving fall pasture usually have a good storage of vitamin A at the beginning of the dry feeding period which tends to reduce the possibility of a vitamin A deficiency from the standpoint of reproduction (150, 183).

The carotene requirement for normal growth is about 14 micrograms per pound of live weight (184). The vitamin A storage in the new-born calf is low (183) but ordinarily the colostrum contains sufficient amount of this vitamin to give the calf a start. Stewart and McCallum (451) determined the vitamin A content of the colostrum from 100 cows and found that it varied from 3.5 to 118 international units per cubic centimeter. The vitamin A content was also found to depend upon the length of dry period. Kramer and associates (283) reported that the colostrum of the first and second days of lactation contained 25 to 28 international units of A per gram for cows receiving supplemented rye pasture and 16 and 20 units for two cows receiving the basal ration. Similar results were reported by Dann (92). A calf weighing 88 pounds would require 2,000 international units per day. It appears from these data that ordinary colostrum would supply sufficient vitamin A for the first few weeks of a calf's life. The requirement during this period has not been adequately investigated. Converse and Meigs (75) are studying this phase of the problem.

Dahlberg and Maynard (90) and Keyes and associates (270) found that

calves fed a good practical ration did not benefit from the addition of a cod liver oil supplement. In their calf starter studies, Savage and Crawford (422) reported favorable results when a fortified cod liver oil was used.

When good hay containing 20 micrograms of carotene per gram is used for calf feeding, one-fourth pound of such hay would meet the requirements of a 100-pound calf. It is apparent that under conditions of good calf management a vitamin A supplement is not necessary, with the possible exception of the first few weeks of a calf's life when whole milk is not fed.

Roughage and the Vitamin A Content of Milk.—The relation of carotene in the roughage to the vitamin A content of milk is of interest from the standpoint of human welfare because milk is the principal source of this factor in the human dietary.

The early work on this subject was reviewed by Hilton and associates (225). These workers showed that butterfat produced by cows on pasture was high in vitamin A. Under winter conditions, timothy hay produced a butterfat of low vitamin A potency while good quality alfalfa hay and soybean hay were effective in maintaining a high vitamin A level equal to pasture feeding. Baumann and Steenbock (28) showed that the carotene and vitamin A potencies of milk were higher during the pasture season and then gradually decreased during the winter feeding period. Hilton and coworkers (226) observed that cows fed artificially cured alfalfa produced milk higher in vitamin A than when fed field cured alfalfa.

Soybean hay made from plants after the beans were well formed suppressed the formation of vitamin A in the butterfat sufficiently to produce a butterfat of only medium high vitamin A activity. Soybean hay made from young plants failed to show this effect when fed to milking cows (226).

The vitamin A content of butterfat increased markedly within two weeks after turning the cows out to pasture (150). The apparent vitamin A recovery in the milk was 47 per cent for a cow receiving 8,432 units of vitamin A per day, 21 per cent for a cow receiving 60,189 units and 10 per cent for a cow receiving 116,101 units daily. The relationship of carotene in the ration to the vitamin A potency of milk has been investigated further by various workers (470, 151, 234).

The effect of feeding various types of silages on the vitamin A content of milk was investigated by several workers (380, 284, 509, 379, 216, 203, 234). In most instances the results of these investigators indicate that the vitamin A potency of the milk was of the same order as the carotene content of the roughage.

ROUGHAGES AS A SOURCE OF VITAMIN D

Green forage (44, 246) or artificially dried hay (33) were practically devoid of vitamin D. According to Steenbock and co-workers (450) the antirachitic potency of hay can be increased by exposure to solar radiation or ultraviolet irradiation. Three pounds of sun-cured timothy hay pro-

tected calves from rickets to one year of age and gradually increasing the hay to six pounds daily prevented rickets to 2.5 years of age (246). Two pounds of sun-cured alfalfa hay were sufficient to protect calves from rickets up to 195 days of age.

Corn cut for silage at the usual stage possessed antirachitic qualities (36). The daily ingestion of 7.0 to 10.0 grams of dry corn silage per kilogram of body weight cured and prevented rickets in yearling calves. The green part of the corn plant was free from this factor while the silks, tassels, and dried leaves were good sources. The corn silage contained 122 to 165 international units of vitamin D per pound of dry matter. The tassels, silks, and dry leaves of corn at the proper stage for ensiling contained 27, 54, and 5.4 international units of vitamin D per gram of dry matter respectively (34). The green part of the plant was devoid of vitamin D.

Bechdel and associates (33) found that 2.5 pounds of sun-cured alfalfa protected calves from rickets and that one pound prevented them from showing the clinical symptoms but failed to maintain normal blood inorganic phosphorus values. On the other hand, 2.5 pounds of dehydrated alfalfa hay failed to prevent rickets. Four to six pounds of prairie hay daily prevented the development of rickets in calves (500). Oat straw apparently contains appreciable amounts of vitamin D (33).

The vitamin D requirement of growing calves was from 1.0 to 1.5 international units per pound of body weight when corn silage was the only source of vitamin D (36). Similar results were secured when viosterol was used as the only source of vitamin in the ration (244). The results of Bechdel and associates (32) indicate a higher vitamin D requirement, namely, three international units per pound of body weight. On the basis of the higher requirement, a 200-pound calf would require 600 international units of vitamin D daily. On the basis of six international units of vitamin D per gram of alfalfa hay (498), only 100 grams of such hay would be required to meet the vitamin D requirement. In other words, calves which have access to sun-cured hay do not need a vitamin D supplement.

Although the amount of vitamin D in the milk may be influenced by the amount in the ration, the liberal feeding of sun-cured hay did not affect the amount of vitamin D in the milk appreciably (35, 499).

Roughage as a Source of Vitamin E.—Evans and Burr (126) reported that vitamin E was present in lettuce and alfalfa. Hathaway and associates (204) tested artificially cured and field-cured alfalfa hay for vitamin E using rats. Fifteen per cent of the ration as artificially cured alfalfa prevented resorption of the young, but the feeding of 15 per cent of field-cured alfalfa was no more effective than 10 per cent of the artificially cured hay. They concluded that artificial drying of alfalfa tends to preserve the vitamin E content to a greater degree than did field curing. In more recent work, these investigators found that 20 per cent of the diet of rats as alfalfa was effective in preventing resorption of the young (202). Zagami (563) re-

ported that legumes furnished enough vitamin E for good reproduction in rats for three generations. Evans and Hoagland (127) found that etiolated and green seedlings of the Canadian field pea grown in an inorganic culture solution and also green seedlings grown in a solution of high sodium chloride content contained vitamin E.

The feeding of sprouted oats which are probably fairly rich in vitamin E benefited 57 females while 31 were not benefited (335). Henke (220) reported that out of 38 cows with irregular breeding behavior, to which sprouted oats were fed, 82 per cent produced calves and that out of 37 cows with a like history, which were not fed sprouted oats, 76 per cent produced calves. The evidence does not indicate that sprouted oats are beneficial in correcting breeding troubles.

Wheat germ oil which is the richest known source of this vitamin has been administered to cattle by several investigators. Unfortunately in most of these studies a check group was not used. Vogt-Moller and Bay (490) and Bay and Vogt-Moller (29) reported the results from treating a total of 70 sterile cows with wheat germ oil, of which 49 became pregnant. Risse (410) found that 10 out of 60 cows conceived within four to six weeks following treatment with wheat germ oil. Jones and Ewalt (259) injected wheat germ oil (10–20 cc.) into sterile cows. They reported favorable results in the case of 15, indefinite results in the case of 33 and negative results in five cows. They stated that no conclusions were warranted as yet. Tutt (476) stated that 17 of the 25 cows treated with wheat germ oil became pregnant and eight remained sterile.

Thomas and associates (466) showed that the goat does not require vitamin E. Whether or not the cow requires this vitamin remains to be proven. The evidence indicates, however, that when ample roughage of a good quality is fed a supplement supplying vitamin E is not warranted.

Roughage as a Source of Other Vitamins.—Recently Wendt (513) reported that milk from pasture-fed cows or cow receiving A. I. V. silage had a nutritive factor which stimulated lactation and the development of the nursing young. Peterson and associates (380) and Kohler and co-workers (280) observed a growth stimulating factor which was different from the known vitamins. This factor was called the "grass juice" factor. Henry and associates (221) failed to demonstrate a special "grass juice" factor in summer milk when compared with winter milk.

Although roughage is a good source of vitamins C, the so-called "vitamin B complex" and vitamin K, these factors will not be discussed in this review since cows apparently do not require them in their ration. Also, the presence of these vitamins in milk is not affected by their level in the ration.

THE UTILIZABLE ENERGY VALUE OF ROUGHAGE

Several methods have been worked out for the evaluation of the energy value of feeds in order to assign to each feed a single energy value. Kellner

used "starch values," Armsby "net energy values," and Fraps "productive energy values," while "total digestible nutrients" has been used almost exclusively in the United States to denote a utilizable energy value. According to the first three systems, the net energy values for roughages are much lower than their total digestible nutrients indicate. Early experiments by Kellner showed that the digestible nutrients in roughages did not produce as much fat in the body of steers as did an equal amount of total digestible nutrients from concentrates. The productive value of the total digestible nutrients in the roughages used showed an inverse relationship to the crude fiber content. Consequently, in evaluating roughages the digestible nutrients were discounted according to the amount of crude fiber present. Associative effects of feeds in digestion and supplementary effects in metabolism were not considered. Several workers (50, 138, 141, 262, 315, 461) contributed evidence in support of the hypothesis that the utilization of metabolizable energy of a ration is a function of its balance with reference to the purpose for which it is balanced.

In other words, the utilizable energy value of roughages varies with the balance of the ration as well as with several other factors. Hamilton (192) using rats found that the growth-promoting values of diets increased as the percentages of protein increased from 4 to 18 per cent, that they remained constant between 18 and 30 per cent protein, and then decreased rapidly when 42 per cent or more of protein was present. Fraps (148) found that corn stover when fed with corn had a productive energy value of 12 therms per 100 pounds and 18.5 therms when fed with corn and linseed meal. Møllgaard (342) showed that when the percentage of net energy consumed as protein ranged from 15 to 25 per cent, the most efficient conversion of metabolizable energy into milk energy occurred.

Kleiber and associates (276) showed that a phosphorus deficiency depressed the availability of metabolizable energy about 10 per cent. Any deficiency which affects growth or milk production probably affects the productive energy of the feed or ration.

Grasses and legumes grown on well balanced soil and used either as pasture or hay, when the protein and digestibility were high, appeared to be about equal to concentrates on a dry basis (62, 360, 116). Such feeds also appeared to exert an energy value for maintenance and milk production about equal to their total digestible nutrient content. The results with a ration of alfalfa alone at the four United States Department of Agriculture substations in long-time feeding experiments likewise suggest that good quality alfalfa hay grown and cured under certain conditions manifests an energy value for milk production about equal to its total digestible nutrient value (171). In this work, however, the total digestible nutrient values were calculated but carbon and nitrogen balances are also needed in conjunction

with such long-time feeding experiments in order to determine the productive energy value of alfalfa hay for maintenance and milk production.

Recent data (63) indicated that high producing dairy cows fed corn silage and a full allowance of a variety of high quality artificially dried hays, but no grain, produced milk as efficiently as cows fed the same quantity of corn silage, a smaller quantity of hay and a half allowance of grain. There was no difference in the efficiency of the conversion of total digestible nutrients to milk energy between the two groups of cows. Only two cows were used in each group.

Ritzman and Benedict (411) reported that one cow on alfalfa alone and one on soybean hay alone produced 10 to 11 kilograms of milk daily. The utilization of the metabolizable energy at this level of lactation was about the same whether the ration was deficient in energy or whether it supplied a surplus of energy. It was also the same when the metabolizable energy was derived from hay alone or when supplied by a mixed ration containing a substantial amount of grain.

The use of either five per cent casein or sucrose as supplements of a mixed herbage ration for rabbits resulted in changing a marked loss in body weight to a substantial gain (81). The deficiency was apparently due to a lack of available energy.

The results with alfalfa alone at Kansas (401), Oregon (258), and Michigan (245) suggest that alfalfa hay does not always manifest a productive energy value comparable to its calculated total digestible nutrients content. Haag (189) postulated that the low milk production on alfalfa alone observed in Oregon might be due to a deficiency of cystine. Rose (414) showed, however, that methionine rather than cystine is the essential amino acid containing sulphur. Cereal grains or beet pulp appears to furnish the essentials which alfalfa hay lacks (245).

Most of the recent data have indicated that hay cured under favorable conditions exert a productive energy value comparable to its total digestible nutrient content. When hay is made under adverse weather conditions variable amounts of the highly digestible nutrients may be lost because of their water-soluble properties. A variation of 10 pounds of total digestible nutrients per 100 pounds of hay would result in about a 60 per cent variation in milk production according to Morrison's requirements. This calculation is based on the assumption that available energy is the limiting factor in the nutritive value of roughages.

The vast amount of data which indicate that the total digestible nutrients of roughage are inferior to the total digestible nutrients of concentrates may be due to, (a) the stage of maturity of the roughage, (b) the loss of nutrients during the curing process, or both. The possibility that grasses and legumes, under certain conditions, may be balanced rations within the limits of the dry matter consumption should stimulate interest in this important economic problem.

ROUGHAGE AS THE SOLE RATION AND WITH VARIOUS SUPPLEMENTS

Pasture.—Although many investigators have studied the chemical composition and digestibility of grasses and legumes cut at various stages of growth, there is yet a paucity of data regarding the feeding value of such roughages when fed as the sole ration. Graves and associates (172) stated that if grass hay is of good quality, and is made from grass at an immature stage of growth, the grass hay alone will supply nutrients for the maintenance and production of somewhat more than 40 pounds of four per cent milk. In their experiments the cows did not consume enough grass silage to provide the nutritive requirements for their maintenance and the production of 30 pounds of four per cent milk but the rate of decline was slower on the silage. The results with grass clippings and grazing indicated that cows will consume enough of these feeds for maintenance and production of a large flow of milk.

Immature grass clippings, artificially dried, replaced a 20 per cent protein grain mixture in a 20-week feeding trial (62). The milk fat and solids-not-fat yields were about equal in each case, and on the basis of total digestible nutrients consumption, the dried grass ration proved to be as good as that containing grain. The substitution of artificially dried young grass for hay in a ration on a basis of equal amounts of total digestible nutrients resulted in an increased milk yield (360).

Elting and La Master (122) reported that substantial barn feeding was necessary to maintain profitable milk production on a pasture consisting largely of Bermuda grass, some Dallis grass and lespedeza, with carpet grass on the lower ground, and carrying slightly more than one cow per acre.

Geith (162) as a result of a study of some 30 dairies, some of which fed concentrates to cows on pasture while others did not, found that the average daily production per cow with concentrates was 35 pounds of milk and without concentrates, 34 pounds. He concluded that high, if not the highest, production can be secured from pastures alone provided they are properly managed.

The effect of turning cows out to pasture on the milk and fat production was investigated by Friis (160) of Denmark in 1899. Records were kept of the milk and fat content for three 10-day periods, preceding and following turning to pasture. These records covered 10 years and represented the production from 1,961 cows. While production rose immediately after turning the cows out to pasture, there was little difference in the average production although the fat content rose slightly.

Graves and associates (171) recently published results of a long-time feeding experiment in which the comparative values for milk production from hay and from silage were presented, each of which was made from immature pasture grass and fed as the sole ration for entire lactation periods. The pasture grasses from which hay or silage was made consisted of brome

grass, or orchard grass, meadow fescue, white clover, perennial rye grass, Kentucky blue grass, and alsike clover. The four cows on the grass and hay ration produced an average of 11,306 pounds of milk and 403 pounds of fat in six lactation periods. Under full feed conditions, they produced on the average 14,958 pounds of milk and 528 pounds of butterfat. The four cows on the grass silage ration produced an average of 9,796 pounds of milk and 358 pounds of fat as compared to an average production of 13,207 pounds of milk and 498 pounds of fat under full feed conditions. Alfalfa hay was substituted for grass hay or grass silage for short periods when these feeds were not available. The decline in milk production during these periods supported the conclusion that the dry matter in immature grass hay or silage was superior for milk production to the dry matter in alfalfa hay which was cut at a stage of maturity in which one-half or more of the plants were in bloom.

Sixteen Jersey cows produced 6,333 pounds of milk and 329 pounds of fat in a year when fed a ration consisting of dried grass and hay. The same cows produced 9,656 pounds of milk and 527 pounds of fat in a year when the roughage was supplemented liberally with grain (167).

One group of cows on an all-roughage ration produced 342 pounds of butterfat yearly while another group which received grain (one pound per three pounds of milk) produced only 373 pounds (208). The all-roughage cows received 74 per cent of their feed supply from pasture while the grain group only received 52 per cent of their nutrients from a pasture under the same pasture conditions. A 4-year summary of two groups of 14 cows each, one with full grain (one pound to three pounds) and the other on limited grain (one pound to six pounds) was recently made (562). The group fed one pound of grain for each six pounds of milk (Jerseys) produced 97 per cent as much milk and butterfat as the full grain group and showed 11 per cent higher income over feed costs.

Wing (528) reported an increase in milk yield of cows for the first two weeks on pasture and a slight decrease during the next three weeks below the daily average for the last three weeks in the barn. Call and Fitch (61) observed an average increase in milk yield of 3.2 pounds of milk daily each time cows were turned on Sudan grass pasture. In an experiment with Ladino clover, significant increases in milk yield occurred when cows were turned from dry feed to fresh pasture.

Willard (522) studied the effect of pasture on milk production. The results are shown in Table 28.

Conserved Roughage Alone.—Woll and Voorhies (534) fed cows on alfalfa hay and silage during periods I and III and on alfalfa hay alone during period II. On alfalfa and silage the cows averaged 17.7 pounds of milk and 0.80 pound of fat, while on alfalfa hay alone they produced 14.1 pounds of milk and 0.63 pound of fat per day. An increase of 26 to 27 per cent in favor of the alfalfa hay and silage was observed in each case.

TABLE 28

Effect of pasture on milk production

No. of cows	Average daily milk production			Increase due to pasture
	Week before pasture	At peak on pasture	Difference	
	lb.	*lb.*	*lb.*	*per cent*
5	23.1	35.6	12.5	54.1
7	28.7	35.0	6.3	21.9
10	40.9	44.0	3.1	7.6

Woll (532) fed these heifers through two lactations on alfalfa hay and green alfalfa. In a later report (60), the following milk and butterfat records were given for all the lactations of the cows used, for alfalfa rations 6,491 pounds of milk and 259 pounds butterfat, for mixed rations 7,337 pounds milk and 323 pounds butterfat.

In addition to the above experiment eight heifers were fed alfalfa hay alone and another group of six heifers was fed alfalfa hay and succulent feeds—green feeds, silage and roots. The group on alfalfa hay alone averaged 6,375 pounds of milk and 223 pounds of butterfat, while the other group produced 7,240 pounds of milk and 257 pounds butterfat.

A herd of 23 cows in a California Cow Testing Association averaged 410 pounds butterfat in a year on alfalfa alone. There was no evidence that the exclusive feeding of alfalfa affected the breeding or fertility of the cows (532).

Reed and associates (401) conducted a long-time feeding experiment where one group of heifers was placed on alfalfa hay alone at six months of age and continued on alfalfa alone throughout the first and second lactations. Another group was placed on alfalfa hay and corn silage, while a third group was fed alfalfa hay, corn silage and grain. Although the appetite of the animals on alfalfa alone was good, their production was very low. The use of corn silage in place of part of the hay also resulted in low production. The production of the control group was considerably higher than the group on roughage alone. This group produced 70 per cent more fat during the first lactation and 101 per cent more fat during the second lactation than heifers fed alfalfa alone.

At the end of the second lactation two animals on alfalfa alone were switched to the regular herd ration. Cow No. 53 increased 119 pounds in butterfat production over the second lactation while No. 56 increased 155 pounds of butterfat. Live weight also increased about 200 pounds per cow during the third lactation.

Similar results were reported by Jones and associates (258) who fed six cows on alfalfa hay alone. Production was very low. The rapid decline in milk production on alfalfa alone suggested a lack of specific nutrients rather than of total digestible nutrients and these investigators questioned

the biological value of the proteins of alfalfa hay. Wheat bran proved a good supplement to alfalfa. Huffman (245) placed cows on alfalfa alone at the time of calving. The cows made good use of the total digestible nutrients in alfalfa for about six weeks. At this point milk production showed a marked drop. A deficiency in the alfalfa was suggested inasmuch as a marked increase in milk production resulted when corn meal replaced an isodynamic quantity of alfalfa.

Jones (257) also reported that eight cows in Oregon fed alfalfa hay alone from one to three years produced 200 pounds of fat annually. No individual cow produced more than 278 pounds of butterfat in one lactation period although there were cows in the group that had had official test records up to 621 pounds of fat in a year. In a continuation of this work, Jones and coworkers (258) reported that average production on long hay was only 53 per cent of the average production on hay and grain. The low production on hay alone was attributed to the lack of a sufficient consumption of total digestible nutrients, and probably of phosphorus.

Alfalfa hay produced in central Oregon under irrigation was compared with that grown in the Willamette Valley without irrigation. One group received the central Oregon hay for 40 days and then after a transition period of 10 days was changed to Willamette Valley hay for 33 days. The second group was started on Willamette Valley hay and changed to the eastern Oregon hay. The results indicated the alfalfa from central Oregon (irrigated) was slightly superior for maintaining milk production. This was probably due to the greater consumption of this hay, 30 pounds per day, compared with 24 pounds daily for the Willamette Valley hay. Second cutting alfalfa of U. S. grade No. 2 was used in the Oregon investigation. Good milk production was usually maintained from four to six weeks after which a sharp decline was observed.

On the other hand, Headley (212) fed four cows for four years on alfalfa hay alone. This group averaged 304 pounds of butterfat annually. Their body weights remained fairly constant from year to year. This work was continued in which five groups were used (213): (a) on alfalfa hay alone, (b) alfalfa hay and grain, (c) alfalfa hay continuously and grain every other lactation period, (d) alfalfa at all times with silage in winter and pasture in summer, but no grain, and (e) same as (d) but with some grain added. The average annual production of cows on the all-roughage rations was 8,090 pounds of milk and 283 pounds of fat. The average annual production of cows receiving grain was 9,498 pounds milk and 331 pounds fat. Grain feeding resulted in 16.9 per cent increase in butterfat production and 17.4 per cent increase in milk production. He observed that butterfat production increased faster than the consumption of total digestible nutrients, thereby making the high-producing cows more economical producers than the low-producing cows. Headley listed the five factors which affect the profitableness of feeding grain as follows: (a) price of hay, (b) price of

grain, (c) price of dairy products, (d) production of cow, and (e) quality of hay.

The feeding of grain to low-producing cows frequently did not increase the income above the feed costs when compared with cows on an all-hay ration. On the other hand, the feeding of grain to high-producing cows resulted in greatly increased production and, under favorable price conditions, a greater income over feed cost.

Seven hundred and two cows in 53 herds in a cow testing association in Nevada for the year 1922–23, fed alfalfa as the sole ration, averaged 7,060 pounds of milk and 263 pounds of fat (214). Cows may be expected to produce 70 per cent as much milk and fat on an all roughage ration as compared with a full grain ration (54). Willard (522) studied the effect of supplementing a roughage ration with grain. Two groups of cows were used. One group was given alfalfa hay and pasture in season and the other group was fed the same roughage but was fed ground barley at the rate of one pound to each five pounds of milk produced. Alfalfa hay was fed in a hay bunk. The alfalfa group produced 9,386 pounds of milk and 310 pounds of fat while the other group produced 10,180 pounds of milk and 323 pounds of fat per lactation period. The high production on roughage alone was probably due to high quality of alfalfa hay and the high character of the pasture used.

A study of a cow testing association's records of 18 herds, involving 214 cows on the Flathead irrigation project in Western Montana, revealed that 8 of the 18 herds, representing 57 per cent of all the cows, received no grain (256). The average production of these herds, fed roughage alone ranged from 200 to 300 pounds of butterfat annually and averaged 268 pounds. The 10 remaining herds which included 92 cows were fed an average of 3.2 pounds of grain per day. Their butterfat production averaged 305 pounds per cow. The difference cannot be attributed entirely to grain feeding.

Dickson and Kopland (103) reported the results of feeding 10 Holstein cows by three different methods: (a) full grain ration, one pound of grain for each three pounds of milk; (b) limited grain, one pound for each six pounds of milk produced; and (c) roughage ration, no grain. The cows were fed all the roughages they would consume. These consisted of alfalfa hay, corn silage, sugar beets, beet pulp, and pasture in season. Ten Holstein cows capable of high production returned an average of 464 pounds of butterfat during 365 days when fed roughage alone. Grain fed at the rate of one pound of grain to each three pounds of milk produced proved wasteful and decidedly uneconomical. One pound of grain fed for each six pounds of milk produced, proved to be an adequate and economical grain ration when fed with all the roughage that the cows could consume. These cows produced 94 per cent as much milk as did cows fed twice as much grain. It would require about 1.64 acres of alfalfa and 3.15 acres of grain to produce the feed required for one cow when given a full-fed grain ration (1 to 3); 2.27 acres of alfalfa and 1.49 acres of grain for a cow on the limited grain

ration (1 to 6); while only 2.57 acres of alfalfa would supply all the digestible nutrients required for body maintenance and milk production for a cow on the roughage ration for one year.

A summary of the work of the United States Department of Agriculture, Bureau of Dairy Industry, has been published recently (173). Fifteen cows fed for a total of 24 lactations on alfalfa hay alone averaged 10,702 pounds of milk and 376 pounds butterfat per year. (The highest yearly record on alfalfa hay alone was 15,109 pounds of milk. This cow consumed 17,092 pounds of hay or one pound of hay per pound of milk). The same cows on full feed produced 15,342 pounds of milk and 538 pounds of fat. Seven cows that were fed the alfalfa hay ration for two consecutive lactation periods averaged 10 per cent less butterfat in the second lactation than in the first. The cows consumed an average of 14,352 pounds of alfalfa. They reached their highest average daily intake of 44.2 pounds during the fifth month of lactation. The highest individual daily consumption of hay was 69 pounds. Fifteen per cent of the hay offered was refused.

The results obtained by the Bureau of Dairy Industry with alfalfa alone are remarkable. The cows made efficient use of the nutrients in the roughage. The alfalfa used in the work was of good quality, most of it would have graded U. S. No. 1 alfalfa. Some was produced under irrigation and some was produced under dry-land conditions.

Alfalfa hay and corn silage as the sole ration was studied by Reed and associates (401) and has already been discussed. Frazer (155) conducted a 6-year home-grown ration demonstration with milking cows. Eleven cows on corn silage and alfalfa hay without grain produced on an average of 8,318 pounds of milk and 284 pounds butterfat in one year. They consumed 39 pounds corn silage and 15.3 pounds of alfalfa daily. The nine cows which were on the demonstration the longest time produced an average of 7,029 pounds of milk per year in 23 complete lactation periods without grain. The roughage was usually of exceptionally good quality and the cows consumed an average of 40 pounds silage and 16 pounds of alfalfa daily.

Dawson and associates (96) reported that, pound for pound, the dry matter in Sudan grass silage was more valuable in maintaining the milk yield than was the dry matter in field cured hay made from Sudan grass at the same stage of maturity.

Several investigators (156, 314, 236) showed that alfalfa hay was superior to timothy hay for milk production. On the other hand, other workers (402, 195) observed satisfactory milk production with timothy hay in comparison with alfalfa when the protein in the grain mixture was adjusted properly. The adverse effects of a timothy ration as reported by Meigs and Converse (325, 326) were due to inferior quality of the timothy fed. Maynard and co-workers (313) have shown that the nitrogen in timothy and clover hays is equally well utilized by milking cows. There was very

little difference in the economy of conversion of feed energy of alfalfa and timothy rations into milk energy (140).

Recently Salisbury and Morrison (419) compared alfalfa and early-cut nitrogen fertilized timothy hay, using milking cows. There was no significant difference in milk or fat production, maintenance of body weight or in the percentage of hay refused.

In sections where alfalfa is adapted, it is the most economical roughage, especially in view of its greater yield of protein and digestible nutrients per acre. When plenty of alfalfa is consumed by dairy cows it is usually unnecessary to feed high protein concentrates. In sections where alfalfa can not be grown successfully, however, timothy and clovers are often used as roughages. The disadvantage of timothy hay in the past, other than its low yield per acre, has been the fact that it was cut at too late a stage of maturity. When dairy feeds are high in price the use of fertilizer may be indicated. Salisbury and Morrison (419) stated that 250 pounds of calcium cyanamid per acre of timothy cut in early bloom stage increased the yield 1,063 pounds of hay per acre in comparison with an unfertilized check. Protein was increased from 8.0 to 9.4 per cent by fertilization. Similar results were reported by other investigators (449, 396, 128).

Sprague and Hawkins (449) stated that high quality roughage from timothy hay and other grasses may be produced in any one of the following three ways: (a) growing mixtures of grasses and legumes which increase both the protein and mineral content; (b) harvesting grasses early when they are still high in protein, preferably grasses receiving nitrogenous fertilizer in the spring; (c) treating grasses at the early head stage with soluble nitrogenous fertilizers and harvesting 10 to 20 days later while the plants are still rich in protein.

Schultz (427) conducted experiments for several years which showed that it is possible to obtain satisfactory production without the use of oil cake and other concentrates. The basal ration consisted of meadow hay, marrow stem kale, silage of vetch mixtures, fodder, beet, and some lucerne hay.

Hodgson and co-workers (233, 232) divided 30 Holstein cows into three groups. One group was fed home-grown grass and clover hay, a second group received silage made from grass and clover and from oats and peas, and another group received a ration containing both hay and silage. The cows in all groups were pastured during the summer. No supplements other than salt and iodine were fed. Reproduction was normal in all three groups. The average butterfat production per year was 254, 251, and 258 pounds respectively for the three groups.

A ration consisting of 13 pounds of alfalfa and 30 pounds of corn silage was found by Lane (290) to be practical and economical in comparison to a ration in which two-thirds of the protein was derived from wheat bran and dried brewers grains.

Supplements to Roughages.—The extensive investigation of the Bureau of Dairy Industry on the feeding value of roughage alone indicate that profitable production may be secured without a concentrate supplement. In most regions in the United States, however, the pasture during the hot, dry months of July and August is of little value and should be properly supplemented. Likewise, the quality of hay available on the farms in many sections will probably not support profitable milk production without a concentrate supplement.

A home-grown ration of alfalfa hay, corn silage, and cereal grains will meet the protein and energy requirements of a Holstein cow producing 40 to 44 pounds of milk per day (196). It was suggested that 20 per cent of the grain mixture be either bran or linseed oil meal to insure against a possible phosphorus deficiency.

A ration of 16.4 pounds crimson clover and 30 pounds of corn silage proved practical when fed in comparison with a ration in which the protein was largely purchased. Also, 10 pounds of crimson clover hay, 36 pounds of cow pea silage and six pounds of corn and cob meal produced as much milk as a ration in which two-thirds of the protein was purchased in the form of dried brewers' grains and cottonseed meal. A ration consisting of 36 pounds of soybean silage, eight pounds of alfalfa hay and six pounds of corn meal produced more milk at less cost per hundredweight than a ration in which the protein was largely supplied by wheat bran, dried brewers' grains and cottonseed meal (291).

In a number of experiments, Billings (46) observed that crimson clover hay wholly replaced purchased proteins. Cow pea silage, crimson clover hay and corn and cob meal proved four per cent more efficient than mixed hay, corn silage and dried brewers' grains. Cow pea hay proved to be a good substitute for purchased proteins. Soybean silage, alfalfa and corn meal proved 11.7 per cent more efficient than a ration of corn silage, corn stalks, wheat bran, dried brewers' grains and cottonseed meal. When alfalfa replaced all of the purchased feed there was a drop of 4.1 per cent in milk yield which was probably not significant.

Caldwell (59) compared a ration of corn meal, corn silage, and alfalfa hay with corn meal, wheat bran, cottonseed meal, corn silage and corn stover, He concluded that alfalfa as well as soybean hay can replace much of the high-priced protein concentrates in the ration of dairy cows.

Horwood and Wells (241) compared a simple home-grown ration consisting of mixed alfalfa and timothy hay (equal parts) and corn with a complex ration consisting of mixed hay, sunflower silage, roots and a grain mixture consisting of five parts corn and one part cottonseed meal. There was no significant difference in milk production between these two rations. In another trial, a ration of alfalfa hay and barley was compared with a ration consisting of alfalfa hay, roots and a grain mixture consisting of 10 parts barley and one part cottonseed meal. The differences were not significant.

Hilton and associates (228) using alfalfa and soybean hays with home-grown grains failed to show a benefit from the addition of protein supplements.

According to True and associates (472), the addition of barley to an exclusive alfalfa hay ration gave only a slight increase in milk yield. When alfalfa hay and corn silage were fed liberally, the feeding of grain at a ratio of one pound of grain to five pounds of milk yielded within five per cent as good results as when the ratio was 1 to 3 (535). Experiments at the Massachusetts (297) and the Louisiana (302) Stations showed that full grain rations gave greater yields than rations in which part of the grain was replaced by roughage. The prices of milk and of the various feeds were considered important factors in deciding which system should be used for greater profit.

Monroe and Allen (343) compared a ration consisting of 30 pounds of alfalfa-timothy hay and 15 pounds of corn silage with one consisting of 15 pounds of hay and 40 to 45 pounds of corn silage. A small amount of grain was fed to the animals in each group. The cows on the heavy hay ration produced a little less milk but almost as much butterfat as did the cows on the light hay ration. Feed costs were lower and the returns over the feed costs were higher on the heavy hay ration. The light hay ration was compared with a moderate hay ration. Moderate hay feeding gave slightly greater production than did the heavy feeding but when the cost of purchased feed was considered, there was little difference between the two systems. These workers reported that the feeding of the heavy hay ration resulted in the retention on the farm of 95 per cent of the milk check, or seven per cent more than on the light hay ration.

The milk and fat production of cows fed roughage alone and with grain as reported in the literature is summarized in table 29.

The feeding of alfalfa alone gave variable results from the standpoint of milk production. The variation may have been due to (a) amount of hay offered, (b) climatic conditions during the growing season, (c) nutrients lost during conservation and storage, and (d) the inheritance for milk production. As has been pointed out the feeding of larger quantities of hay than cows will clean up, results in an increase in the quantity and quality of the dry matter consumed. The effect of climate and the losses during the curing process have been discussed.

Some of the high milk production records reported on rations of roughage alone may have been due in part to the liberal grain feeding during the previous lactation period. In a test of an all roughage system of feeding heifer calves should be placed on the roughage alone at 9 to 12 months of age.

The variable results with alfalfa hay alone indicate the advisability of supplementing the roughage with grain in order to secure economic milk production. The use of the old thumb rules for feeding grain, however,

should be replaced by rules which permit the economical production of milk and fat.

TABLE 29

Feeding value of roughage alone and with various supplements for milk production

	No grain						Hay, grain with or without silage		
	Hay or silage			Hay plus corn sil.					
	Lact.	Milk	Fat	Lact.	Milk	Fat	Lact.	Milk	Fat
	days	*lb.*	*lb.*	*days*	*lb.*	*lb.*	*days*	*lb.*	*lb.*
Kansas alfalfa hay									
(401) 1st lact.	305	4,097	150	305	4,524	154	305	6,268	230
2nd lact.	305	4,151	150	305	4,351	161	305	6,044	222
Nevada alfalfa hay									
(212)	365	8,644	304	.....	.....	.....	365	10,352	359
Montana alfalfa hay,									
(103) corn silage,									
pasture	365	13,295	464	.....	.....	.....	365	17,851	544
Oregon whole alfalfa	305	4,421	166	.....	.....	.....	305	7,208	278
(258) cut alfalfa	305	5,696	214	.....	.....	.....	.....	.....	.....
Calif.* 1st lact.	335	5,743	204	.....	.....	.....	355	7,359	297
(532) 2nd lact.	354	6,372	286	.....	.....	.....	302	7,420	351
U.S.D.A. alfalfa hay									
(173) 1st lact.	365	10,974	395	.....	.....	.....	.....	.....	.....
2nd lact.	365	10,239	357	.....	.....	.....	.....	.....	.....
Tenn. alfalfa, corn									
(208) silage, pasture	.....	.....	.....	365	5,883	342	365	6,659	373
Ill. all roughage (155)	.....	.....	.....	365	8,318	284	.....	.....	.....
Wash. hay & pasture	365	7,953	254	.....	.....	.....	.....	.....	.....
(232) hay & silage	365	7,857	251	.....	.....	.....	.....	.....	.....
hay, silage &									
pasture	365	7,889	258	.....	.....	.....	.....	.....	.....
Wash. & alfalfa hay,									
U.S.D.A. silage, pasture	339	11,361	403	.....	.....	.....	365	15,815	559
(232) alfalfa hay	359	10,702	376	.....	.....	.....	365	16,255	521
(171) pasture grass									
hay	359	11,180	399	.....	.....	.....	365	15,240	537
grass silage	353	9,796	368	.....	.....	.....	365	13,207	498
artificially									
dried legume									
hay & pasture	337	6,333	329	.....	.....	.....	361	9,656	527
Wyoming alfalfa hay,									
(522) pasture	386	9,386	310	.....	.....	.....	404	10,180	323

* Alfalfa hay and fresh alfalfa.

RULES FOR FEEDING GRAIN

The trend toward more appetizing, nutritious roughages has necessitated a revision of the thumb rules for feeding roughage and grain. Frazer (155) formulated the following rules for economic feeding as a result of the more milk per acre demonstration:

(1) Full feed of corn silage and good alfalfa hay, or three and one-third pounds of silage and one and one-third pounds of hay per day per 100 pounds of live weight.

(2) For the larger breeds producing 3.5 to 4.0 per cent milk—one pound

of grain to each two and one-half pounds of milk produced above 20 pounds per day.

(3) For the smaller breeds producing 5.0 to 5.5 per cent milk—one pound of grain to each two pounds of milk produced above 12 pounds per day.

Headley (215) from the results on feeding alfalfa alone and alfalfa and grain suggested that Holstein cows giving less than 30 pounds of milk daily be fed good alfalfa alone but feed 0.4 pound of grain per pound of milk above 30 pounds per day. For Jerseys—no grain for cows producing less than 25 pounds milk daily and for those producing more than 25 pounds, feed one pound of grain for each 2.5 pounds of milk.

The grain feeding schedules to use with various qualities roughages are given by Morrison (350). These suggestions for grain feeding appear to be satisfactory.

SUMMARY

The nutritive value of roughages for dairy cattle depends upon the amount of dry matter consumed, the chemical composition and the coefficient of digestibility of the dry matter.

Dry matter consumption is affected by factors inherent in the animal and those inherent in the ration and environment. There is a wide variation in dry matter consumption of cows on the same roughage. The palatability of roughages is not a reliable criterion to use in estimating the amount which cows will consume. The trend toward the use of properly managed pasture, and hays and silage made from grasses and legumes cut at an earlier stage of maturity has resulted in an increase in roughage consumption per 100 pounds of body weight. Most cows will consume about three pounds of hay equivalent per 100 pounds of body weight which is a 50 per cent increase in roughage consumption over the old thumb rule for roughage feeding.

The chemical composition has been shown to vary with the stage of maturity, soil conditions and climate. Young plants are characterized by their high protein content, low cellulose and lignin content and a high digestibility of their dry matter. The decreased digestibility of the dry matter with increasing maturity is believed to be associated in some way with lignification although the total amount of lignin does not appear to be the determining factor. The greater use of properly managed pasture before the coefficient of digestibility drops makes the use of this class of roughage profitable. The data indicate that highly digestible roughage exerts a productive energy value about equal to that of concentrates on the dry basis.

The use of non-lignified grasses and legumes for winter feeding is very limited. This is due to the low yields and the difficulty encountered in the field curing of such roughages. Fertilization to increase the yield of roughage and its conservation in the silo after wilting make possible the use of highly nutritious roughage throughout the year.

The nutritive value of hays cut at the usual stage of maturity depends upon the nutrients conserved during the curing process. As has been pointed out by several investigators, the loss of nutrients during the field curing of hay is rather high during good hay making weather but the loss of nutrients is very large during adverse curing weather. Better methods of conserving roughages are needed because poor hay making weather prevails in many dairy sections. The cost of artificial dehydration of hays appears somewhat high at the present time.

Recent experiments indicate that grasses and legumes may be conserved economically in the silo with a loss of only about 10 per cent of the dry matter. In several experiments, however, the loss of dry matter in roughage conserved as silage was rather high. Most investigations indicate, however, that the addition of from one to three per cent of molasses is advisable in the making of grass and legume silage. Inorganic acids may also be used to preserve these crops in the silo but molasses has the additional advantage of preserving the crop and contributing to the nutrition of the animal. Of the inorganic acids, phosphoric acid appears to have a slight advantage in silage making. It is easy to apply and it may contribute to the phosphorus requirement of the animal and to the fertility of the soil. Several investigators have reported that grasses and legumes make excellent silage without any treatment providing the ensiled material has a moisture content of about 70 per cent and the trapped air is expelled by fine cutting.

Many of the silage investigations, however, have been conducted either in small containers or in very large silos. In both cases the results may not represent the conditions in the average farm silo of about 50- to 100-ton capacity. In large silos the increased pressure may affect the moisture and carotene content of the silage as well as influence the capacity of the silo. There is very little difference in the dry matter capacity of the average silo for corn, grass or legume silage when the moisture and fineness of cut are about the same, but in large silos, more dry matter can be stored as grass or legume silage. Additional data is needed in regard to the conservation of grasses and legumes in the average farm silo.

Roughage protein appears to be well-balanced from the standpoint of the essential amino acids necessary for growth and milk production. The possibility of protein synthesis in the rumen by the rumen flora has been indicated.

Although grasses and legumes are probably very low in true fat, the results obtained with alfalfa alone suggest that when a liberal roughage program is followed there is little likelihood of encountering a fat deficiency. The possibility of a fat deficiency or of some factors closely associated with fat should, however, be considered.

The conservation of soluble carbohydrates in roughage is of practical importance because unfavorable weather conditions result in their loss in hay making. They may be of importance in maintaining the health of cattle

during the barn feeding period. Ketosis has been shown to occur in cows fed rations low in soluble carbohydrates. This is explained on the basis of the new theory of rumen digestion which postulates the conversion of foods which stagnate in the rumen to fatty acids by bacteria. The soluble carbohydrates have a greater chance of escaping bacterial action.

Grasses and legumes are excellent sources of carotene when used as pasture but when used as hay, a large amount of the carotene is lost in field curing and during storage. The amount present in field cured hay is sufficient to meet the physiological needs of cattle for growth and reproduction when roughage is fed liberally. The conservation of carotene in roughages is of importance in the production of milk high in vitamin A. Several investigators have reported the preservation of large amounts of carotene in grass and legume silage by the use of either molasses or inorganic acids. The results obtained by the United States Department of Agriculture, Bureau of Dairy Industry, indicate that a preservative is not necessarily needed for the preservation of carotene in grass and legume silages.

When green material is placed in the silo, the resultant silage is low in vitamin D inasmuch as this vitamin is formed in the cured plant material during solar radiation. The feeding of four or five pounds of sun-cured roughage per cow daily will meet the physiological needs of the animal for this vitamin during the winter months. Grasses appear to be good sources of vitamin E but whether or not cattle require this factor has not been ascertained. There is no evidence to indicate that the other vitamins in roughage are required in the ration of cattle.

Roughages are usually good sources of calcium and cattle have been shown to utilize about 50 per cent of the calcium in the ration when the supply of this element is rather low. There appears to be very little likelihood of a calcium deficiency occurring among cattle when they are allowed plenty of roughage.

Phosphorus is the mineral element which is most likely to be deficient in the ration of cattle when they are fed a heavy roughage ration because the phosphorus content of most roughage is low. The phosphorus content of roughage, under certain conditions, may be increased by phosphate fertilization but numerous instances have been recorded to show that the ordinary application of phosphate fertilizers to the soil did not influence the phosphorus content of the plant. The soil type and the moisture conditions are frequently the determining factors which influence the phosphorus content of the plant. In sections where the roughage is low in this element, the addition of a phosphorus supplement to the ration of milking cows is indicated.

Roughages grown on soils containing iodine are good sources of this element but on those farms where "big neck" or goiter occur among newborn calves, an iodine supplement should be supplied.

All of the other mineral elements required by cattle have been shown to

be adequately supplied by roughage with the possible exception of a few localities where iron, copper or cobalt are needed as supplements.

The high production of dairy cows on roughage alone as reported by several investigators is of great practical importance and also of scientific interest. In these studies cows fed alfalfa alone appeared to make exceedingly good use of the total digestible nutrients for maintenance and milk production. Kellner, Armsby and Fraps have discounted the digestible nutrients in roughage according to its crude fiber content in arriving at "starch values," "net energy values," and "productive energy values." Apparently the low productive energy value of the digestible nutrients in the roughage studied by the many workers was due to some factor other than the crude fiber content. Alfalfa hay as the sole ration in several experiments, however, did not give results comparable to its total digestible nutrient content. In view of the variations in the productive energy values of alfalfa hay which has been reported in the literature, a grain supplement should probably be fed to cows in medium and high milk production. Rules have been suggested for feeding grain with roughage of good quality.

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REFERENCES

(1) Ahlgren, H. L., G. Bohstedt, and O. S. Aamodt. J. Am. Soc. Agron. 30: 1020. 1938.
(2) Allen, L. A., and J. Harrison. Ann. Appl. Biol., (Lond.) 23: 538. 1936.
(3) Allen, L. A., S. J. Watson, and W. S. Ferguson. J. Agr. Sc. 27: 294. 1937.
(4) Allen, N. N. J. Dairy Sc. 17: 379. 1934.
(5) Ames, J. W., and G. E. Boltz. Ohio Agr. Exp. Sta. Bull. 247. 1912.
(6) Amos, A., and H. E. Woodman. J. Agr. Sc. 12: 337. 1922.
(7) Archibald, J. G., A. B. Beaumont, R. E. Stitt, and R. S. Snell. J. Am. Soc. Agron. 25: 123. 1933.
(8) ————, and E. Bennett. Mass. Agr. Exp. Sta. Bull. 300. 1933.
(9) ————, and E. Bennett. J. Agr. Res. 51: 83. 1935.
(10) ————, K. J. Kucinski, R. O. Brooke, and S. L. Freeman. J. Dairy Sc. 21: 59. 1938.
(11) ————, and P. R. Nelson. J. Am. Soc. Agron. 21: 686. 1929.
(12) Arizona Agr. Exp. Sta. 45th. Ann. Report 41. 1934.
(13) Armsby, H. P. U. S. D. A. Bur. Animal Ind. Bull. 139. 1911.
(14) ————. The Nutrition of Farm Animals. The Macmillan Co. N. Y. 572. 1917.
(15) ————, H. J. Patterson, and G. L. Holt. Penn. Agr. Exp. Sta. Report No. 17: 55. 1888.
(16) Arny, A. C., R. E. Hodgson, and G. H. Nesom. Minn. Agr. Exp. Sta. Bull. 263. 1930.
(17) Askew, H. O., and J. K. Dixson. New Zealand J. Sci. Tech. 19: 317. 1937.
(18) ————, and P. W. Maunsell. New Zealand J. Sci. Tech. 19: 337. 1937.
(19) Aston, B. C. New Zealand J. Agr. 37: 242. 1928.
(20) Atkeson, F. W., and G. C. Andersen. Idaho Agr. Exp. Sta. Bull. 214. 1935.

(21) ————————, W. J. Peterson, and A. E. Aldous. J. Dairy Sc. 20: 557. 1937.
(22) Bailey, K. Biochem. J. 31: 1396. 1937.
(23) Barnell, H. R. New Phytologist 37: 85. 1938.
(24) Barnes, E. E. J. Am. Soc. Agron. 16: 241. 1924.
(25) Bartlett, S. J. Dairy Res. 7: 222. 1936.
(26) ————————, and A. G. Cotton. J. Dairy Res. 9: 263. 1938.
(27) ————————, K. M. Henry, S. K. Kon, L. W. Osborne, S. Y. Thompson, and J. Tinsley. Biochem. J. 32: 2024. 1938.
(28) Baumann, C. A., and H. Steenbock. J. Biol. Chem. 101: 547. 1933.
(29) Bay, F., and P. Vogt-Moller. Vet. J., (Lond.) 90: 288. 1934.
(30) Beaumont, A. B. Mass. Agr. Exp. Sta. Bull. 281. 1932.
(31) Bechdel, S. I. Pa. Agr. Exp. Sta. Bull. 178. 1923.
(32) ————————, N. W. Hilston, N. B. Guerrant, and R. A. Dutcher. Pa. Agr. Exp. Sta. Bul. 364. 1938.
(33) ————————, K. G. Landsburg, and O. J. Hill. Pa. Agr. Exp. Sta. Bull. 291. 1933.
(34) Bechtel, H. E., and C. A. Hoppert. Mich. Agr. Exp. Sta. Quart. Bull. 18: 153. 1936.
(35) ————————, ————————. J. Nutrit. 11: 537. 1936.
(36) ————————, C. F. Huffman, C. W. Duncan, and C. A. Hoppert. J. Dairy Sc. 19: 359. 1936.
(37) Becker, R. B., and L. W. Gaddum. J. Dairy Sc. 20: 737. 1937.
(38) ————————, W. M. Neal, C. R. Dawson, and P. T. D. Arnold. Fla. Agr. Exp. Sta. Bull. 255. 1932.
(39) ————————, W. M. Neal, and A. L. Shealy. Fla. Agr. Exp. Sta. Tech. Bull. 262. 1933.
(40) Bender, C. B. N. J. Agr. 15: 2. 1933.
(41) ————————, and J. W. Bartlett. N. J. Agr. Exp. Sta. Cir. 263. 1932.
(42) ————————, and H. H. Tucker. N. J. Agr. Exp. Sta. Cir. 374. 1937.
(43) ————————, H. H. Tucker, W. C. Krueger, K. O. Pfau, and A. S. Fox. J. Dairy Sc. 19: 137. 1936.
(44) Bethke, R. M., D. C. Kennard, and M. C. Kik. J. Biol. Chem. 63: 377. 1925.
(45) ————————, and C. A. Kick. Ohio Agr. Exp. Sta. Bull. 431: 117. 1929.
(46) Billings, G. A. N. J. Agr. Exp. Sta. Bull. 204. 1907.
(47) Blair, A. W., and A. L. Prince. J. Agr. Res. 44: 579. 1932.
(48) Blakemore, F., J. A. Nicholson, and J. Steward. Vet. Rec., (Lond.) 49: 415. 1937.
(49) Boyd, F. T., O. S. Aamodt, G. Bohstedt, and E. Truog. J. Am. Soc. Agron. 30: 569. 1938.
(50) Braman, W. W., A. Black, O. J. Kahlenberg, L. Voris, R. W. Swift, and E. B. Forbes. J. Agr. Res. 50: 1. 1935.
(51) Brouwer, E., and N. D. Dijkstra. J. Agr. Sc. 28: 695. 1938.
(52) Brown, B. A. J. Am. Soc. Agron. 21: 673. 1939.
(53) Brunton, W. Ministry Agr. and Fisheries. London. Misc. Pub. 60. 1928.
(54) Bureau of Dairy Industry Mimeograph Pamphlet. March, 1934.
(55) Burke, E., A. H. Johnson, S. G. Scott, B. L. Herrington, and J. Green. Mont. Agr. Exp. Sta. Report 34: 88. 1927.
(56) ————————, I. J. Nygard, and W. McK. Martin. Mont. Agr. Exp. Sta. Bull. 280. 1933.
(57) Burr, G. O., and M. M. Burr. J. Biol. Chem. 82: 345. 1929.
(58) Buston, H. W. Biochem. J. 29: 196. 1935.
(59) Caldwell, R. E. Ohio Agr. Exp. Sta. Bull. 267. 1913.

(60) California Agr. Exp. Sta. Ann. Report 72. 1919.
(61) Call, L. E., and J. B. Fitch. Kan. Agr. Exp. Sta. Cir. 80. 1920.
(62) Camburn, O. M. Vt. Agr. Exp. Sta. Bull. 359. 1933.
(63) ————, and C. H. Jones. Vt. Agr. Exp. Sta. Bull. 446. 1939.
(64) ————, H. B. Ellenberger, J. A. Newlander, and C. H. Jones. Vt. Agr. Exp. Sta. Bull. 434. 1938.
(65) Capen, R. G., and J. A. LeClerc. J. Agr. Res. 46: 665. 1933.
(66) Carroll, W. E. Utah Agr. Exp. Sta. Bull. 126. 1913.
(67) Carruthers, W., and J. A. Voelcker. Joint report by the consulting botanist and the consulting chemists on the grass experiments conducted by the society 1895–1897. J. Roy. Agr. Soc. Eng. 3rd. Ser. 9: 137. 1898.
(68) Casalis, C. E. M. Hoard's Dairyman 79: 140. 1934.
(69) Chibnall, A. C., and H. J. Channon. Biochem. J. 21: 479. 1927.
(70) ————, and L. S. Nolan. J. Biol. Chem. 62: 173. 1924.
(71) Christensen, F. W., and T. H. Hopper. N. D. Agr. Exp. Sta. Tech. Bull. 260. 1932.
(72) Clark, I. D., R. W. Frey, and H. L. Hyland. J. Agr. Res. 58: 131. 1939.
(73) Clark, R. W. Mont. Agr. Exp. Sta. Bull. 94. 1913.
(74) Converse, H. T., and E. B. Meigs. Proc. Am. Soc. Animal Production 141. 1932.
(75) ————, ————. Report Chief Bur. Dairy Ind. p. 19. 1938.
(76) Cooke, W. W. Colo. Agr. Exp. Sta. Bull. 57. 1900.
(77) Crabtree, M. G., and E. M. Mason. Med. Research Council Special Report Series (Gr. Brit.) No. 217: 13. 1936.
(78) Crampton, E. W. Empire J. Expl. Agr. 2: 337. 1934.
(79) ————. Feedstuffs 11: 20. 1938.
(80) ————. Sci. Agr. 19: 345. 1939.
(81) ————, and D. A. Finlayson. Empire J. Expl. Agr. 3: 331. 1935.
(82) ————, and L. A. Maynard. J. Nutrit. 15: 383. 1938.
(83) ————, and L. C. Raymond. Macdonald College Tech. Bull. 13. 1934.
(84) Crasemann, E., and Steiner. Cited by Watson and associates. J. Agr. Sc. 27: 225. 1937.
(85) Crozier, A. A. Mich. Agr. Exp. Sta. Bull. 141: 115. 1937.
(86) Cunningham, O. C., and L. H. Addington. N. Mex. Agr. Exp. Sta. Bull. 257. 1938.
(87) ————, ————, and W. E. Watkins. N. Mex. Agr. Exp. Sta. Bull. 206. 1932.
(88) Curtiss, R. S. Origin—History—Research. The Robert S. Curtiss Publ. Co., Raleigh, N. C. 1938.
(89) Daalen, C. K. Van. Report 3rd. Grassel and Conf. Zurich: 34. 1934. Abst. by A. J. Peters. A digest of some world pasture research literature. (Exclusive of the continental United States and Canada.) No. 994, 1937.
(90) Dahlberg, A. C., and L. A. Maynard. J. Dairy Sc. 20: 59. 1937.
(91) Daniel, H. A., and H. J. Harper. J. Am. Soc. Agron. 27: 644. 1935.
(92) Dann, W. J. Biochem. J. 27: 1998. 1933.
(93) Davis, W. L. J. Agr. Sc. 16: 280. 1926.
(94) Dawson, J. R. U. S. D. A. Year Book 220. 1930.
(95) ————. U. S. D. A. Year Book 221. 1930.
(96) ————, R. R. Graves, and A. G. Van Horn. U. S. D. A. Tech. Bull. 352. 1933.
(97) Deetz, R. J. Landw. 21: 57 1873. Abst. by A. J. Peters. A digest of some world pasture research literature. (Exclusive of the continental United States and Canada.) No. 292. 1937.

(98) De Ruijter de Wildt, J. C. Versl. RijkslandbProefst., 's Grav. 40: 875. 1934. Cited by Watson and Ferguson. J. Agr. Sc. 27: 1. 1937.
(99) Dexter, S. T. Plant Physiol. 11: 843. 1936.
(100) ————, and L. A. Moore. Mich. Agr. Exp. Sta. Quart. Bull. 20: 75. 1937.
(101) Dice, J. R. N. D. Agr. Exp. Sta. Bull. 174: 44. 1924.
(102) ————. N. D. Agr. Exp. Sta. Bull. 194: 55. 1926.
(103) Dickson, W. F., and D. V. Kopland. Mont. Agr. Exp. Sta. Bull. 293. 1934.
(104) Dinsmore, S. C. Nev. Agr. Exp. Sta. Bull. 63: 37. 1907.
(105) Dixon, J. K. New Zealand J. Sc. Tech. 19: 326. 1937.
(106) Dodd, D. R. J. Am. Soc. Agron. 27: 853. 1935.
(107) Douglass, E., J. W. Tobiska, and C. E. Vail. Colorado Agr. Exp. Sta. Tech. Bull. 4. 1933.
(108) Dustman, R. B., and A. H. Van Landingham. J. Am. Soc. Agron. 22: 719. 1930.
(109) Du Toit, P. J., J. G. Loury and A. I. Milan. Onderstepoort J. Vet. Sc. Animal Ind. 5: 215. 1935.
(110) Eckles, C. H. Missouri Agr. Exp. Sta. Bull. 162. 1919.
(111) ————, R. B. Becker, and L. S. Palmer. Minn. Agr. Exp. Sta. Bull. 229. 1926.
(112) ————, and T. W. Gullickson. Proc. Am. Soc. Animal Production 16. 1927.
(113) ————, ————, and L. S. Palmer. Minn. Agr. Exp. Sta. Tech. Bull. 91. 1932.
(114) ————, L. S. Palmer, T. W. Gullickson, C. P. Fitch, W. L. Boyd, L. Bishop, and J. W. Nelson. Cornell Vet. 25: 22. 1935.
(115) Ehrenberg, P., and V. Prittwitz. Landw. Vers. 125: 101. 1936. Abstract Exp. Sta. Record 77: 237. 1937.
(116) Ellenberger, H. B., J. A. Newlander, and C. H. Jones. Vt. Agr. Exp. Sta. Bull. 295. 1929.
(117) ————, ————, ————. Vt. Agr. Exp. Sta. Bull. 342. 1932.
(118) ————, ————, ————. Vt. Agr. Exp. Sta. Bull. 331. 1931.
(119) Ellett, W. B., and L. Carrier. J. Am. Soc. Agron. 7: 85. 1915.
(120) Ellis, J. H., and O. G. Caldwell. Sc. Agr. 16: 521. 1936.
(121) Elting, E. C. J. Dairy Sc. 18: 440. 1935.
(122) ————, and J. P. LaMaster. S. C. Agr. Exp. Sta. Ann. Rpt. 44: 58. 1931.
(123) ————, ————, and J. H. Mitchell. S. C. Agr. Exp. Sta. Bull. 308. 1937.
(124) Elvehjem, C. A., and E. B. Hart. J. Biol. Chem. 82: 473. 1929.
(125) Enlow, C. R., and J. M. Coleman. J. Am. Soc. Agron. 21: 845. 1929.
(126) Evans, H. M., and G. O. Burr. Anat. Record 29: 356. 1925.
(127) ————, and D. R. Hoagland. Am. J. Physiol. 80: 702. 1927.
(128) Evans, M. W., and L. E. Thatcher. J. Agr. Res. 56: 347. 1938.
(129) Evans, R. E. J. Agr. Sc. 21: 806. 1931.
(130) Fagan, T. W. Welsh J. Agr. 4: 92. 1928.
(131) ————, and W. M. Ashton. Welsh J. Agr. 13: 129. 1937.
(132) ————, ————. Welsh J. Agr. 14: 160. 1938.
(133) ————, and W. E. J. Milton. Welsh J. Agr. 7: 246. 1931.
(134) Ferguson, W. S., A. H. Lewis, and S. J. Watson. Nature 141: 553. 1938.
(135) Fingerling, G., E. Bretsch, A. Losche, and G. Arndt. Landw. Vers. Sta. 83: 180. 1913. Abs. in Exp. Sta. Record 31: 667. 1914.
(136) Fleischmann, F. Cited by E. J. Hoffman, and M. A. Bradshaw. J. Agr. Res. 54: 159. 1937.

(137) FOLEY, R. C., E. J. MONTAGUE, AND C. H. PARSONS. Mass. Agr. Exp. Sta. Bull. 262. 1930.
(138) FORBES, E. B. J. Nutrit. 14: 419. 1937.
(139) ————, *et al.* Ohio Agr. Exp. Sta. Bull. Nos. 295, 308, 330, and 363. 1916–1922.
(140) ————, AND LEROY VORIS. J. Nutrit. 5: 395. 1932.
(141) ————, R. W. SWIFT, A. BLACK, AND O. J. KAHLENBERG. J. Nutrit. 10: 461. 1935.
(142) ————, A. C. WHITTIER, AND R. C. COLLISON. Ohio Agr. Exp. Sta. Bull. 222. 1910.
(143) FOSTER, L., AND L. A. MERRILL. Utah Agr. Exp. Sta. Bull. 61. 1899.
(144) FOTH, G. Abs. in Exp. Sta. Record 32: 364. 1915.
(145) FRAPS, G. S. N. C. Agr. Exp. Sta. Bull. 172. 1900.
(146) ————. Texas Agr. Exp. Sta. Bull. 290. 1922.
(147) ————. Texas Agr. Exp. Sta. Bull. 418. 1930.
(148) ————. Texas Agr. Exp. Sta. Bull. 436. 1931.
(149) ————, AND A. R. KEMMERER. Texas Agr. Exp. Sta. Bull. 557. 1937.
(150) ————, O. C. COPELAND, AND R. TREICHLER. Texas Agr. Exp. Sta. Bull. 495. 1934.
(151) ————, AND A. R. KEMMERER. Texas Agr. Exp. Sta. Bull. 560. 1938.
(152) ————, AND J. B. RATHER. Texas Agr. Exp. Sta. Bull. 150. 1912.
(153) ————, ————. Texas Agr. Exp. Sta. Bull. 162. 1913.
(154) ————, AND R. TREICHLER. Ind. and Eng. Chem. 25: 465. 1933.
(155) FRASER, W. J. Dairy Farming. John Wiley and Sons, Inc. 130. 1930.
(156) ————, AND C. C. HAYDEN. Ill. Agr. Exp. Sta. Bull. 146. 1910.
(157) FREAR, W. W., W. T. CARTER, C. A. BROWNE, JR., R. O. BROOKS, AND C. W. NORRIS. Pa. Agr. Exp. Sta. Rpt. 40. 1904.
(158) FRED, E. B., AND W. H. PETERSON. Wis. Agr. Exp. Sta. Bull. 362. 1924.
(159) ————, ————, AND J. A. ANDERSON. J. Biol. Chem. 46: 319. 1921.
(160) FRISS, F. 45. Report K. Vet. Landbohojskoles Lab. Landokon Forsog (Copenhagen). 57, 88. 1889. Abs. in Exp. Sta. Record 11: 782. 1899–1900.
(161) GARNER, F. H., AND H. G. SANDERS. J. Agr. Sc. 28: 541. 1938.
(162) GEITH, R. Jahrb. uber Weide. 11: 59. 1933. Abs. A. J. Pieters. A digest of some world pasture research literature (Exclusive of the continental United States and Canada). No. 330. 1937.
(163) GIBSON, G., AND C. F. HUFFMAN. Mich. Agr. Exp. Sta. Quart. Bull. 21: 258. 1939.
(164) GODDEN, WM. Minerals in Pastures and Their Relation to Animal Nutrition. H. K. Lewis and Co. Ltd. 14. 1929.
(165) ————. Agr. Progress 8. 1931 (reprint).
(166) GOLDING, J. Proc. 8th World's Dairy Congress. 44. 1928.
(167) GORDON, E. D., AND W. M. HURST. U. S. D. A. Cir. 443. 1937.
(168) GORINI, C. Abs. in Exp. Sta. Record 32: 363. 1915.
(169) GRAVES, R. R. Report Chief of Bur. Dairy Ind. 12. 1929.
(170) ————. Report Chief Bur. Dairy Ind. 10. 1938.
(171) ————, J. R. DAWSON, AND D. V. KOPLAND. U. S. D. A. Tech. Bull. 649. 1938.
(172) ————, ————, ————, AND T. W. MOSELEY. U. S. D. A. Tech. Bull. 381. 1933.
(173) ————, ————, ————, ————, A. L. WATT, AND A. G. VAN HORN. U. S. D. A. Tech. Bull. 610. 1938.
(174) GREEN, J. Mont. Agr. Exp. Sta. Bull. 283. 1934.

(175) GREENHILL, A. W. J. Agr. Sc. 20: 573. 1930.
(176) ———. Biochem. J. 30: 412. 1936.
(177) ———. Empire J. Expl. Agr. 4: 145. 1936.
(178) GRIMMETT, R. E. R., AND F. B. SHORLAND. New Zealand J. Agr. 50: 367. 1935.
(179) GRIZZARD, A. L. J. Am. Soc. Agron. 27: 81. 1935.
(180) GRUNDER, M. S. J. Agr. Res. 46: 375. 1933.
(181) GUANZON, G. A., AND W. M. SANDSTROM. J. Agr. Res. 55: 581. 1937.
(182) GUILBERT, H. R. J. Nutrit. 10: 45. 1935.
(183) ———, AND G. H. HART. J. Nutrit. 8: 25. 1934.
(184) ———, ———. J. Nutrit. 10: 409. 1935.
(185) ———, AND S. W. MEAD. Hilgardia 6: 1. 1931.
(186) ———, ———, AND H. C. JACKSON. Hilgardia 6: 13. 1931.
(187) GULLICKSON, T. W., L. S. PALMER AND W. L. BOYD. Minn. Agr. Exp. Sta. Tech. Bull. 105: 47. 1935.
(188) GUTHRIE, J. D. Am. J. Botany 16: 716. 1929.
(189) HAAG, J. R. J. Nutrit. 4: 363. 1931.
(190) ———, I. R. JONES, AND P. M. BRANDT. J. DAIRY SC. 15: 23. 1932.
(191) ———, J. S. JONES, I. R. JONES, AND P. M. BRANDT. J. DAIRY SC. 12: 445. 1929.
(192) HAMILTON, T. S. J. Nutrit. 13: Suppl. 16. 1937.
(193) HART, E. B., B. A. BEACH, E. J. DELWICHE, AND E. G. BAILEY. Wis. Agr. Exp. Sta. Bull. 389. 1927.
(194) ———, H. J. DEOBALD, AND G. BOHSTEDT. Wis. Agr. Exp. Sta. Bull. 439. 1937.
(195) ———, F. B. HADLEY, AND G. C. HUMPHREY. Wis. Agr. Exp. Sta. Res. Bull. 112. 1932.
(196) ———, AND G. C. HUMPHREY. Wis. Agr. Exp. Sta. Bull. 417. 1930.
(197) ———, O. L. KLINE, AND G. C. HUMPHREY. J. Agr. Res. 45: 507. 1932.
(198) ———, H. STEENBOCK, C. A. HOPPERT, R. M. BETHKE, AND G. C. HUMPHREY. J. Biol. Chem. 54: 75. 1922.
(199) ———, ———, AND G. C. HUMPHREY. Wis. Agr. Exp. Sta. Res. Bull. 49. 1920.
(200) HART, G. H., AND H. R. GUILBERT. Calif. Agr. Exp. Sta. Bull. 560. 1933.
(201) HARTWIG, H. B. Hoard's Dairyman 75: 667. 1930.
(202) HATHAWAY, I. L., AND H. P. DAVIS. Nebr. Agr. Exp. Sta. Res. Bull. 73. 1934.
(203) ———, ———, AND J. C. BRAUER. Nebr. Agr. Exp. Sta. Res. Bull. 101. 1938.
(204) ———, ———, AND R. R. GRAVES. Nebr. Agr. Exp. Sta. Res. Bull. 62. 1932.
(205) HAUGE, S. M. J. Assoc. Off. Agr. Chem. 17: 304. 1934.
(206) ———. J. Biol. Chem. 108: 331. 1935.
(207) ———, AND W. AITKENHEAD. J. Biol. Chem. 93: 657. 1931.
(208) HAZELWOOD, B. P. Tenn. Agr. Exp. Sta. Cir. 58. 1936.
(209) HEADDEN, W. P. Colo. Agr. Exp. Sta. Bull. 35. 1896.
(210) ———. Colo. Agr. Exp. Sta. Bull. 39. 1897.
(211) ———. Colo. Agr. Exp. Sta. Bull. 124. 1907.
(212) HEADLEY, F. B. Nev. Agr. Exp. Sta. Bull. 119. 1930.
(213) ———. Nev. Agr. Exp. Sta. Bull. 140. 1935.
(214) ———, E. W. KNIGHT, AND L. E. CLINE. U. S. D. A. Cir. 352. 1925.
(215) ———, AND C. VENSTROM. Nev. Agr. Exp. Sta. Bull. 118. 1930.
(216) HEGSTED, D. M., AND G. BOHSTEDT. J. DAIRY SC. 20: 430. 1937.
(217) HELLER, V. G., M. JONES, AND L. PURSELL. Okla. Agr. Exp. Sta. Bull. 229. 1935.

(218) HELMS, W. Agr. Gaz. N. S. Wales 26: 41. 1915.
(219) HENDRY, G. W. Calif. Agr. Exp. Sta. Bull. 394. 1925.
(220) HENKE, L. A. J. Agr. Res. 51: 51. 1935.
(221) HENRY, K. M., E. W. IKIN, AND S. K. KON. J. Dairy Res. 8: 282. 1937.
(222) HIGGINS, F. L. Minn. Agr. Exp. Sta. Tech. Bull. 83. 1932.
(223) HILL, J. H., AND E. C. WHITE. J. Bact. 18: 43. 1929.
(224) HILLS, J. L. Vt. Agr. Exp. Sta. Rpt. 109. 1893.
(225) HILTON, J. H., S. M. HAUGE, AND J. W. WILBUR. J. DAIRY SC. 16: 355. 1933.
(226) ———, ———, ———. J. DAIRY SC. 18: 795. 1935.
(227) ———, J. W. WILBUR, AND W. F. EPPLE. Ind. Agr. Exp. Sta. Bull. 346. 1929.
(228) ———, ———, ———. Ind. Agr. Exp. Sta. Bull. 407. 1936.
(229) HODGSON, R. E., AND J. C. KNOTT. J. Agr. Res. 45: 557. 1932.
(230) ———, ———. Wash. Agr. Exp. Sta. Bull. 348. 1937.
(231) ———, ———, R. R. GRAVES, AND H. K. MURER. J. Agr. Res. 50: 149. 1935.
(232) ———, ———, V. L. MILLER, AND H. K. MURER. Wash. Agr. Exp. Sta. Bull. 366. 1938.
(233) ———, ———, H. K. MURER, AND R. R. GRAVES. Wash. Agr. Exp. Sta. Bull. 354. 1937.
(234) ———, ———, ———, ———. J. Agr. Res. 57: 513. 1938.
(235) HOFFMAN, E. J., AND M. A. BRADSHAW. J. Agr. Res. 54: 159. 1937.
(236) HOLDAWAY, C. W., W. B. ELLETT, J. F. EHEART, AND H. G. CUNNINGHAM, JR. Va. Agr. Exp. Sta. Tech. Bull. 45. 1932.
(237) HONCAMP, F. Landw. Vers. Sta. 100: 79. 1922. Abs. Exp. Sta. Record 49: 669. 1923.
(238) HOPKIRK, C. S. M., AND R. E. R. GRIMMETT. New Zealand J. Agr. 56: 21. 1938.
(239) HOPPER, T. H., AND L. L. NESBITT. N. D. Agr. Exp. Sta. Bull. 236. 1930.
(240) HORWITT, M. K., G. R. COWGILL, AND L. B. MENDEL. J. Nutrit. 12: 255. 1936.
(241) HORWOOD, R. E., AND J. G. WELLS, JR. Mich. Agr. Exp. Sta. Quart. Bull. 18: 248. 1936.
(242) HUFFMAN, C. F. Mich. Agr. Exp. Sta. Quart. Bull. 11: 3. 1928.
(243) ———. Proc. Am. Soc. Animal Production 44. 1934.
(244) ———. Proc. XI World's Dairy Congress, Berlin 1: 397. 1937.
(245) ———. J. DAIRY SC. 21: No. 5, 101. 1938.
(246) ———, AND C. W. DUNCAN. J. DAIRY SC. 18: 511. 1935.
(247) ———, ———. J. DAIRY SC. 19: 440. 1936.
(248) ———, ———, C. S. ROBINSON, AND L. W. LAMB. Mich. Agr. Exp. Sta. Tech. Bull. 134. 1933.
(249) ———, C. S. ROBINSON, AND O. B. WINTER. J. DAIRY SC. 13: 432. 1930.
(250) HULTZ, F. S. Wyo. Agr. Exp. Sta. Bull. 134. 1923.
(251) HUNT, C. H., P. R. RECORD, AND R. M. BETHKE. Ohio Agr. Exp. Sta. Bull. 576. 1936.
(252) HUNTER, O. W. J. Agr. Res. 15: 571. 1918.
(253) IJDO, J. B. H. Biochem. J. 30: 2307. 1936.
(254) Institute of Agricultural Engineering. Univ. of Oxford Bull. 2. 1926.
(255) ITALLIE, T. B. VAN. Verslag. Landbouwk. Onderzoek. Rijkslandbouwproefstat. 40 A: 639. 1934. Abs. by A. J. Pieters. A digest of some world pasture research literature (Exclusive of the continental United States and Canada). No. 1002. 1937.

(256) JOHNSON, S. E., J. O. TRETSVEN, M. EZEKIEL, AND O. V. WELLS. Mont. Agr. Exp. Sta. Bull. 264. 1932.
(257) JONES, I. R. Proc. 19th Ann. Meet. West. Div. Am. Dairy Sc. Assoc. 1933.
(258) ————, P. M. BRANDT, AND J. R. HAAG. Ore. Agr. Exp. Sta. Bull. 328. 1934.
(259) ————, AND H. P. EWALT. Proc. 22nd. Ann. Meet. West. Div. Am. Dairy Sc. Assoc. 61. 1936.
(260) ————, ————, AND J. R. HAAG. Proc. 24th. Ann. Meet. West. Div. Am. Dairy Sc. Assoc. 30. 1938.
(261) JORDAN. Cited by P. F. Trowbridge, L. D. Haigh, and C. R. Moulton. Mo. Agr. Exp. Sta. Res. Bull. 20. 1915.
(262) KAHLENBERG, O. J., A. BLACK, AND E. B. FORBES. J. Nutrit. 13: 97. 1937.
(263) KANE, E. A., H. G. WISEMAN, AND C. A. CARY. J. Agr. Res. 55: 837. 1937.
(264) KANNENBERG. Weide. u. Futterb. Beilage zur Deut. Landw. Tierz. 7: 1–2. 1932. Abs. by A. J. Pieters. A digest of some world pasture research literature (Exclusive of the continental United States and Canada) No. 362. 1937.
(265) KELLERMANN, J. H. Onderstepoort J. Vet. Sc. Animal Ind. 4: 437. 1935.
(266) KELLNER, O. Cited by P. F. Trowbridge, L. D. Haigh, and C. R. Moulton. Mo. Agr. Exp. Sta. Res. Bull. 20. 1915.
(267) ————. The Scientific Feeding of Animals. (Translation.) Duckworth, London. 365. 1915.
(268) ————. Cited by H. P. Armsby. The Nutrition of Farm Animals. The Macmillan Co., N. Y., 660. 1917.
(269) KENNEY, R. Kans. State Board Agr. Quart. Report, June, 241. 1916.
(270) KEYES, E. A., H. B. ELLENBERGER, AND C. H. JONES. Proc. XI World's Dairy Congress, Berlin 1: 112. 1937.
(271) KICK, C. H., P. GERLAUGH, A. F. SCHALK, AND E. A. SILVER. Ohio Agr. Exp. Sta. Bull. 592. 1938.
(272) KIESSELBACH, T. A., AND A. ANDERSON. U. S. D. A. Tech. Bull. 235. 1931.
(273) ————, ————. Nebr. Agr. Exp. Sta. Res. Bull. 36. 1926.
(274) KIRSCH, W., AND H. HILDEBRANDT. Die Silofutterberitung Nach dem Kaltgarverfahren. Berlin, Parey. 79. 1930.
(275) KLEIBER, M. H. Report of the conference on energy metabolism. Nat'l Res. Council 50. 1935.
(276) ————, H. R. GOSS, AND H. R. GUILBERT. J. Nutrit. 12: 121. 1936.
(277) KNOTT, J. C., AND R. E. HODGSON. J. DAIRY SC. 17: 409. 1934.
(278) ————, ————. Proc. West. Div. Am. Dairy Sc. Assoc. 35. 1938.
(279) KOFFMAN, M. Skand. Vet.-Tidskr. 27: 413. 1937.
(280) KOHLER, G. O., C. A. ELVEHJEM, AND E. B. HART. Wis. Agr. Exp. Sta. Bull. 438: 131. 1937.
(281) KONEKAMP, A. Fortschr. der landw. 4: 519. 1929. Abs. by A. J. Pieters. A digest of some world pasture research literature (Exclusive of the continental United States and Canada). No. 383. 1937.
(282) KOTAKE, Y. Ann. Review Biochem. 4: 225. 1935.
(283) KRAMER, M. M., M. D. BAIR, B. L. KUNERTH, AND W. H. RIDDELL. J. Agr. Sc. 56: 277. 1938.
(284) KRAUSS, W. E., AND R. G. WASHBURN. J. DAIRY SC. 19: 454. 1936.
(285) KREBS, K. Biedermanns Zentr. (B) Tierernähr. 9: 394. 1937.
(286) KUHLMAN, A. H., W. D. GALLUP, AND E. WEAVER. J. DAIRY SC. 19: 433. 1936.
(287) KUCHLER, L. F. Cited by S. J. Watson and W. S. Ferguson. J. Agr. Sc. 27: 1. 1937.

(288) Ladd. Cited by P. F. Trowbridge, L. D. Haigh, and C. R. Moulton. Mo. Agr. Exp. Sta. Res. Bull. 20. 1915.
(289) Lamb, L. W., O. B. Winter, C. W. Duncan, C. S. Robinson, and C. F. Huffman. J. Dairy Sc. 17: 233. 1934.
(290) Lane, C. B. N. J. Agr. Exp. Sta. Bull. 161. 1902.
(291) ———. N. J. Exp. Sta. Bull. 174. 1904.
(292) Laupper, G. Mater. Etude Calamites. 3: 112. 1926. Abs. in Exp. Sta. Record 59: 282. 1928.
(293) Lawes, J. B., and J. H. Gilbert. Trans. Roy. Soc. (London) B. 192: 139. 1900.
(294) LeClerc, J. A., and J. F. Breazeale. U. S. D. A. Year Book 389. 1908.
(295) Leukel, W. A., J. P. Camp, and J. M. Coleman. Fla. Agr. Exp. Sta. Bull. 269. 1934.
(296) Lincoln, L. Mauritius Dept. Agr. Sc. Ser. Bull. 26. 1937.
(297) Lindsey, J. B., and J. G. Archibald. Mass. Agr. Exp. Sta. Bull. 291. 1932.
(298) ———, ———, and P. R. Nelson. J. Agr. Res. 42: 883. 1931.
(299) Lines, E. W. L. J. Council Sc. Ind. Res. 8: 117. 1935.
(300) Loomis, W. E. J. Am. Soc. Agron. 29: 697. 1937.
(301) Lugg, J. W. H. Biochem. J. 32: 2114. 1938.
(302) Lush, R. H. La. Agr. Exp. Sta. Bull. 241. 1933.
(303) ———. La. Agr. Exp. Sta. Bull. 299. 1938.
(304) ———, and J. L. Fletcher. J. Dairy Sc. 17: 733. 1934.
(305) Marek, J., O. Wellman, and Urbanyi. Arch. wiss. prakt. Tierheilk. 73: 73. 1938. Abs. by Nutrition Abstracts Revs. 8: 541. 1938.
(306) Marshall, F. H. A., and E. T. Halnan. Physiology of Farm Animals. Cambridge Univ. Press. 1932.
(307) Marston, H. R. Austral. Council Sc. Ind. Res. 8: 111. 1935.
(308) ———, R. G. Thomas, D. Murnane, E. W. Lines, I. W. McDonald, H. O. Moore, and L. B. Bull. Austral. Council Sc. Ind. Res. Bull. 113. 1938.
(309) Martin, J. H., J. F. Couch, and R. R. Briese. J. Am. Soc. Agron. 30: 725. 1938.
(310) Mather, T. H. Sc. Agr. 10: 35. 1929.
(311) Maynard, L. A., and C. M. McCay. N. Y. (Cornell) Agr. Exp. Sta. Bull. 543. 1932.
(312) ———, ———, H. W. Williams, and L. L. Madsen. N. Y. (Cornell) Agr. Exp. Sta. Bull. 593. 1934.
(313) ———, R. C. Miller, and W. E. Krauss. N. Y. (Cornell) Agr. Exp. Sta. Mem. 113. 1928.
(314) McCandlish, A. C., and E. Weaver. Ia. Agr. Exp. Sta. Bull. 212. 1923.
(315) McClure, F. J., L. Voris, and E. B. Forbes. J. Nutrit. 8: 295. 1934.
(316) McHargue, J. S. J. Agr. Res. 30: 193. 1925.
(317) ———. J. Am. Soc. Agron. 17: 368. 1925.
(318) ———. Ind. Eng. Chem. 19: 274. 1927.
(319) ———, W. R. Roy, and J. G. Pelphrey. J. Am. Soc. Agron. 24: 562. 1932.
(320) ———, D. W. Young, and R. K. Calfee. J. Am. Soc. Agron. 27: 559. 1935.
(321) McNaught, K. L. New Zealand J. Sc. Tech. 20: 14. 1938.
(322) Meigs, E. B. U. S. D. A. Year Book 324. 1935.
(323) ———, N. R. Blatherwick, and C. A. Cary. J. Biol. Chem. 40: 469. 1919.
(324) ———, and H. T. Converse. J. Dairy Sc. 15: 171. 1932.
(325) ———, ———. Proc. Am. Soc. Animal Production 58. 1933.
(326) ———, ———. J. Dairy Sc. 16: 317. 1933.

(327) ————————, W. A. Turner, T. S. Harding, A. M. Hartman, and F. M. Grant. J. Agr. Res. 32: 833. 1926.
(328) ————————, ————————, E. A. Kane, and L. A. Shinn. J. Agr. Res. 51: 1. 1935.
(329) ————————, and T. E. Woodward. J. Dairy Sc. 4: 185. 1921.
(330) Meyer, D. Abs. in Exp. Sta. Record 34: 767. 1916.
(331) Midgley, A. R. J. Am. Soc. Agron. 29: 498. 1937.
(332) Millar, C. E. J. Am. Soc. Agron. 30: 507. 1938.
(333) Miller, E. J. Biochem. J. 29: 2344. 1935.
(334) ————————, and A. C. Chibnall. Biochem. J. 26: 392. 1932.
(335) Miller, F. W., and R. R. Graves. U. S. D. A. Tech. Bull. 321. 1932.
(336) Miller, H. G. J. Am. Chem. Soc. 43: 2656. 1921.
(337) Miller, M. W., and G. E. Bearse. Wash. Agr. Exp. Sta. Bull. 292. 1934.
(338) Mills, A. A. Utah Agr. Exp. Sta. Bull. 44. 1896.
(339) Mitchell, H. H., and T. S. Hamilton. The Biochemistry of the Amino Acids. The Chemical Catalog Co., N. Y. 179. 1929.
(340) ————————, F. J. McClure. Nat'l. Research Council Bull. 99. 1937.
(341) Mitchell, J. H., J. D. Warner, and K. S. Morrow. S. C. Agr. Exp. Sta. Bull. 252. 1928.
(342) Møllgaard, H. Cited by H. H. Mitchell. Proc. Am. Soc. Animal Production 29. 1937.
(343) Monroe, C. F., and H. Allen. Ohio Agr. Exp. Sta. Bull. 538. 1934.
(344) ————————, and A. E. Perkins. Ohio Agr. Exp. Sta. Bull. 579: 76. 1937.
(345) Montana Agr. Exp. Sta. Ann. Report. No. 43. 18. 1936.
(346) Moore, L. A. J. Dairy Sc. 21: (Abstracts) 114. 1938.
(347) ————————, C. F. Huffman, and C. W. Duncan. J. Nutrit. 9: 533. 1934.
(348) Morris, S. Nutrition Abstracts and Revs. 6: 273. 1936.
(349) ————————, N. C. Wright, and A. B. Fowler. J. Dairy Res. 7: 97. 1936.
(350) Morrison, F. B. Feeds and Feeding. Morrison Publishing Co., Ithaca, N. Y. 20th Ed. 1936.
(351) Morse, F. W. N. H. Agr. Exp. Sta. 2nd. Ann. Rpt. 63. 1890.
(352) Mortimer, G. B., and H. L. Ahlgren. J. Am. Soc. Agron. 28: 515. 1936.
(353) Moxon, A. L. S. D. Agr. Exp. Sta. Bull. 311. 1937.
(354) Murray, J. A. J. Agr. Sc. 16: 574. 1926.
(355) Neal, W. M., and C. F. Ahmann. J. Dairy Sc. 20: 741. 1937.
(356) Neidig, R. E., C. W. Colver, H. P. Fishbun, and C. L. Van Ende. Idaho Agr. Exp. Sta. Bull. 104. 1918.
(357) Nevens, W. B. J. Dairy Sc. 4: 552. 1921.
(358) ————————. Ill. Agr. Exp. Sta. Bull. 391. 1933.
(359) ————————, and A. F. Kuhlman. J. Dairy Sc. 19: 611. 1936.
(360) Newlander, J. A. Vt. Agr. Exp. Sta. Bull. 350. 1933.
(361) ————————. Vt. Agr. Exp. Sta. Bull. 386. 1935.
(362) ————————. Vt. Agr. Exp. Sta. Bull. 400. 1935.
(363) ————————, H. B. Ellenberger, O. M. Camburn, and C. H. Jones. Vt. Agr. Exp. Sta. Bull. 430. 1938.
(364) ————————, and C. H. Jones. Vt. Agr. Exp. Sta. Bull. 348. 1932.
(365) Norman, A. G. J. Agr. Sc. 23: 216. 1933.
(366) ————————. J. Agr. Sc. 25: 529. 1935.
(367) ————————. Biochem. J. 30: 1354. 1936.
(368) ————————. Agr. Progress 14: 141. 1937.
(369) ————————, and H. L. Richardson. Biochem. J. 31: 1556. 1937.
(370) Norris, L. W., and C. E. Resch. Biochem. J. 31: 1945. 1937.

(371) ORR, J. B. Minerals in Pastures and Their Relationship to Animal Nutrition. H. K. Lewis and Co., Ltd. London 15. 1929.
(372) ORR, J. B. Empire Marketing Board Bull. 18. 1929.
(373) PALMER, L. S., C. P. FITCH, T. W. GULLICKSON, AND W. L. BOYD. Cornell Vet. 25: 229. 1935.
(374) PATUREL, G. J. Agr. Prac. 76: 524. 1912. Abs. in Chem. Abs. 7: 2075. 1913.
(375) PATTERSON, D. D. J. Agr. Sc. 23: 615. 1933.
(376) PERKINS, A. E., C. C. HAYDEN, C. F. MONROE, W. E. KRAUSS, AND R. G. WASHBURN. Ohio Agr. Exp. Sta. Bi-Monthly Bull. 23: 3. 1938.
(377) PETER, A. M. Ky. Agr. Exp. Sta. Bull. 87: 111. 1900.
(378) PETERSEN, W. E. J. DAIRY SC. 15: 283. 1932.
(379) ————————, J. B. FITCH, AND N. N. ALLEN. J. DAIRY SC. 20: 429. 1937.
(380) PETERSON, W. H., H. R. BIRD, AND W. M. BEESON. J. DAIRY SC. 20: 611. 1937.
(381) ————————, G. BOHSTEDT, H. R. BIRD, AND W. M. BEESON. J. DAIRY SC. 18: 63. 1935.
(382) ————————, E. B. FRED, AND J. H. VERHULST. J. Biol. Chem. 46: 329. 1921.
(383) PHILLIPS, M., AND M. J. GOSS. J. Agr. Res. 51: 301. 1935.
(384) PIERRE, W. H., AND R. R. ROBINSON. J. Am. Soc. Agron. 29: 477. 1937.
(385) PIPER, C. V., and associates. U. S. D. A. Year Book 285. 1924.
(386) PIRAUX, E. Bull. Inst. Agron. et stas. recherches Gembloux. 3: 239. 1934. Abs. in Exp. Sta. Record 73: 520. 1938.
(387) ————————, A. HACQUART, F. JOASSIN, AND F. DESMET. Bull. Inst. Agron. et stas. recherches Gembloux. 4: 105. 1935. Cited by S. J. Watson and W. S. Ferguson. J. Agr. Sc. 27: 1. 1937.
(388) PITTMAN, D. W. Utah Agr. Exp. Sta. Bull. 247. 1934.
(389) POCHON, J. Compt. rend. soc. biol. 113: 1323. 1933.
(390) ————————. Compt. Rend. 199: 983. 1934.
(391) ————————. Ann. Inst. Pasteur. 55: 676. 1935.
(392) POLLARD, A., AND A. C. CHIBNALL. Biochem. J. 28: 326. 1934.
(393) POLLOCK, E. O., AND W. H. HOSTERMAN. U. S. D. A. Farmers' Bull. 1770. 1937.
(394) POWELL, E. B. Proc. Am. Soc. Animal Production 40. 1938.
(395) PRATT, A. D., AND C. W. HOLDAWAY. Va. Agr. Exp. Sta. Bull. 309. 1937.
(396) PRINCE, F. S., T. G. PHILLIPS, P. T. BLOOD, AND G. P. PERCIVAL. N. H. Agr. Exp. Sta. Bull. 306. 1938.
(397) PRJANISCHNIKOW, N. D., AND M. F. TOMME. Biedermanns Zentr. B. Tierernähr. 8: 104. 1936. Abs. in Nutrition Abstracts and Revs. 6: 231. 1936.
(398) RAGSDALE, A. C., AND C. W. TURNER. Mo. Agr. Exp. Sta. Res. Bull. 65. 1924.
(399) RATHER, J. B. Texas Agr. Exp. Sta. Bull. 169. 1914.
(400) REED, O. E., AND J. B. FITCH. Kan. Agr. Exp. Sta. Bull. 217. 1917.
(401) ————————, ————————, AND H. W. CAVE. Kan. Agr. Exp. Sta. Bull. 233. 1924.
(402) ————————, AND C. F. HUFFMAN. Mich. Agr. Exp. Sta. Tech. Bull. 105. 1930.
(403) ————————, ————————, AND L. H. ADDINGTON. J. DAIRY SC. 11: 488. 1928.
(404) REID, W. D. New Zealand J. Agr. 51: 139. 1935.
(405) REMN, T., AND F. WEISKE. Abs. in Exp. Sta. Record 32: 364. 1915.
(406) RICHARDSON, C. U. S. D. A. Ann. Report 231. 1883.
(407) RICHTER, F. Proc. XI World's Dairy Congress, Berlin, 2: 140. 1937.
(408) RICHTER, K., AND J. HERBST. Landw. Jahrb. 86: 22. 1938.
(409) RIDDELL, W. H., J. S. HUGHES, AND J. B. FITCH. Kan. Agr. Exp. Sta. Tech. Bull. 36. 1934.
(410) RISSE, W. Inaug. Diss. Hanover. Abs. Vet. Bull. 8: 48. 1938.

(411) RITZMAN, E. G., AND F. G. BENEDICT. Carnegie Inst. Wash. Pub. No. 494. 1938.
(412) ROBERTS, E. J. Grass Drying. His Majesty's Stationery Office. (Lond.). 1937.
(413) ROETHE, H. E. Agr. Eng. 18: 547. 1937.
(414) ROSE, W. C. Science 86: 298. 1937.
(415) ————————. Physiol. Revs. 18: 109. 1938.
(416) ROTHWELL, G. B. Dominion of Canada. Dept. of Agr. Dominion Exp. Farms. Rpt. of Dominion Animal Husbandryman, 18. 1924.
(417) RUSSELL, W. C. J. Biol. Chem. 85: 289. 1929.
(418) ————————, M. W. TAYLOR, AND D. F. CHICHESTER. N. J. Agr. Exp. Sta. Bull. 560. 1934.
(419) SALISBURY, G. W., AND F. B. MORRISON. N. Y. (Cornell) Agr. Exp. Sta. Bull. 694. 1938.
(420) SALMON, S. C., C. O. SWANSON, AND C. W. MCCAMPBELL. Kan. Agr. Exp. Sta. Tech. Bull. 15. 1925.
(421) SAMARANI, F. Hoard's Dairyman 63: 806. 1922.
(422) SAVAGE, E. S., AND C. H. CRAWFORD. N. Y. (Cornell) Agr. Exp. Sta. Bull. 622. 1935.
(423) SCHAIBLE, P. J., S. L. BANDEMER, AND J. A. DAVIDSON. Mich. Agr. Exp. Sta. Tech. Bull. 159. 1938.
(424) SCHARRER, K., AND A. STROBEL. Cited by Wm. Godden. Agr. Progress 8: 1931.
(425) SCHEUNERT, A., AND M. SCHIEBLICH. Biedermanns Zentr. B. Tierernähr. 6: 112. 1934. Chem. Abs. 28: 5102. 1935.
(426) SCHNEIDER, K. Weide. u. Futterb. Beilage 36. zur Deut. Landw. Tierz. 7: 13–15. 1932. Abs. by A. J. Pieters. A digest of some world pasture research literature (Exclusive of the continental United States and Canada.) No. 449. 1937.
(427) SCHULTZ, J. Weidew. Flutterban Beil. deutsch. landwirtsch. Tierz. 10: 45. 1935.
(428) SCHULZE, E. Landw. Jahrb. Schweiz. 6: 72. 1892. Abs. Exp. Sta. Record 5: 337. 1893–94.
(429) SCOTT, S. G. J. Agr. Res. 38: 113. 1929.
(430) SEMPLE, A. T., H. N. VINALL, C. R. ENLOW, AND T. E. WOODWARD. U. S. D. A. Misc. Pub. 194: 52. 1934.
(431) SHAW, T. Soiling Crops and the Silo. Orange Judd Co., N. Y. 327. 1902.
(432) SHEPHARD, J. B., AND T. E. WOODWARD. J. DAIRY SC. 21: 89. 1938.
(433) SHUEY, R. C. J. Ind. Eng. Chem. 6: 910. 1914.
(434) SHUTT, F. T. Can. Exp. Farms. Div. Chem. Report 1927. 55. 1928.
(435) ————————, AND S. N. HAMILTON. J. Agr. Sc. 24: 341. 1934.
(436) SHUTTLEWORTH, A. E. Ont. Agr. Col. and Exp. Farm. Rpt. 1896. 32. 1897–98. Abs. in Exp. Sta. Record 9: 479. 1897–98.
(437) SJOLLEMA, B. Biochem. Z. 267: 151. 1933.
(438) SMITH, J. A. B., AND C. C. CHIBNALL. Biochem. J. 26: 218. 1932.
(439) SMITH, M. C. J. Agr. Res. 53: 681. 1936.
(440) ————————, AND I. A. BRIGGS. J. Agr. Res. 46: 229. 1933.
(441) ————————, AND E. B. STANLEY. J. Agr. Res. 56: 69. 1938.
(442) SMUTTS, D. B., AND A. I. MALAN. Onderstepoort J. Vet. Sc. Animal Ind. 10: 193. 1938.
(443) SOTOLA, J. J. Agr. Res. 35: 361. 1927.
(444) ————————. J. Agr. Res. 40: 79. 1930.
(445) ————————. J. Agr. Res. 47: 919. 1933.
(446) ————————. J. Agr. Res. 54: 399. 1937.
(447) SPEER, J. H., E. C. WISE, AND M. C. HART. J. Biol. Chem. 82: 105. 1929.

(448) SPRAGUE, H. B., N. F. FERRIS, AND C. S. CATHART. N. J. Agr. Exp. Sta. Bull. 565. 1934.
(449) ————, AND A. HAWKINS. N. J. Agr. Exp. Sta. Bull. 644. 1938.
(450) STEENBOCK, H., E. B. HART, C. A. ELVEHJEM, AND S. W. F. KLETZIEN. J. Biol. Chem. 66: 425. 1925.
(451) STEWART, J., AND J. W. MCCALLUM. J. Agr. Sc. 28: 428. 1938.
(452) STRASSL. Berlin. Munch. tierarztl. Wochenschr. 27: 397. 1938. Nutrition Abstracts and Revs. 8: 617. 1939.
(453) STREPKOV, S. M. Biochem. Z. 290: 378. 1937.
(454) STUART, L. S., AND L. H. JAMES. J. Agr. Res. 42: 657. 1931.
(455) SULLIVAN, N. P., AND I. A. MANVILLE. Am. J. Pub. Health 27: 1108. 1937.
(456) SVENSKA, H. O. Mosskulturför. Tidskr. 46: 154. 1932. Abstract by A. J. Pieters. A digest of some world pasture research literature. (Exclusive of the continental United States and Canada.) No. 1188. 1937.
(457) SWANSON, C. O., L. E. CALL, AND S. C. SALMON. J. Agr. Res. 18: 299. 1919.
(458) ————, AND W. L. LATSHAW. J. Ind. Eng. Chem. 8: 726. 1916.
(459) ————, AND E. L. TAGUE. J. Agr. Res. 10: 275. 1917.
(460) ————, ————. J. Agr. Res. 15: 113. 1918.
(461) SWIFT, R. W., O. J. KAHLENBERG, L. VORIS, AND E. B. FORBES. J. Nutrit. 8: 197. 1934.
(462) TAYLOR, M. W., AND W. C. RUSSELL. J. Nutrit. 16: .1 1938.
(463) THEILER, A., P. J. DUTOIT, AND A. I. MALAN. Onderstepoort J. Vet. Sc. Animal Ind. 8: 375. 1937.
(464) ————, H. H. GREEN, AND P. J. DU TOIT. J. Dept. Agr. South Africa 8: 460. 1924.
(465) ————, ————, ————. J. Agr. Sc. 17: 291. 1927.
(466) THOMAS, B. H., C. Y. CANNON, S. H. MCNUTT, AND G. UNDERBJERG. J. DAIRY SC. 21: 98. 1938.
(467) THOMAS, B., AND F. E. MOON. Empire J. Expl. Agr. 6: 235. 1938.
(468) TIEMANN, A., AND G. MÜLLER. Arch. Tierernähr. u. Tierzucht. 9: 253. 1933. Abstract by A. J. Pieters. A digest of the world pasture research literature. (Exclusive of the continental United States and Canada). No. 478. 1937.
(469) TOENNIES, G. Growth 1: 337. 1937.
(470) TREICHLER, R., M. A. GRIMES, AND G. S. FRAPS. Texas Agr. Exp. Sta. Bull. 513. 1935.
(471) TROWBRIDGE, P. F., L. D. HAIGH, AND C. R. MOULTON. Mo. Agr. Exp. Sta. Res. Bull. 20. 1915.
(472) TRUE, G. H., F. W. WOLL, AND E. C. VOORHIES. Calif. Agr. Exp. Sta. Bull. 256. 1915.
(473) TRUNINGER, E. Cited by E. J. Hoffman and M. A. Bradshaw. J. Agr. Res. 54: 159. 1937.
(474) TUFF. Proc. of the World's Dairy Congress 2: 1494. 1923.
(475) TURK, K. L., F. B. MORRISON, AND L. A. MAYNARD. J. Agr. Res. 48: 555. 1934.
(476) TUTT, J. F. Vet. J. (Lond.) 89: 416. 1933.
(477) UNDERWOOD, E. J., AND J. F. FILMER. Australian Vet. J. 11: 84. 1935.
(478) UPSON, F. W. Nebr. Agr. Exp. Sta. Press Bull. 46. 1915.
(479) USTYANTZEV, V. P. O Pitanii Travoyadnuikh Zhivotnuikh Klyetchatkoi i Ghrubuimi. Kiev: VII–174 1906. Abstract Exp. Sta. Record 18: 863. 1906–1907.
(480) VAIL, C. E., T. W. TOBISKA, AND E. DOUGLASS. Colo. Agr. Exp. Sta. Tech. Bull. 18. 1936.
(481) VAN GEYNUM, J., AND J. W. PETTE. Vereeniging tot Exploitatie eener Proetizuivel-

boerderij te Hoorn. Verslag over het jaar 1936. Nieuwe Handeldrukkerij fuima Firma A. Houdijk. Hoorn 1937.
(482) VANDECAVEYE, S. C., AND L. V. BOND. J. Am. Soc. Agron. 28: 491. 1936.
(483) VINALL, H. N., AND H. L. WILKINS. J. Am. Soc. Agron. 28: 562. 1936.
(484) VIRTANEN, A. I. Contribution from the Lab. of Valio. No. 2. 1934.
(485) ————————, AND T. LAINE. Nature 137: 237. 1936.
(486) ————————. Nature 137: 779. 1936.
(487) ————————. Cattle Fodder and Human Nutrition. Cambridge Univ. Press. 78. 1938.
(488) ————————, S. V. HAUSEN, AND S. SAATSTAMOINEN. Biochem. Z. 267: 179. 1933.
(489) ————————, AND T. LAINE. Biochem. J. 30: 1509. 1936.
(490) VOGT-MOLLER, P., AND F. BAY. Vet. J. 87: 165. 1931.
(491) FELLENBERG, TH. Biochem. Z. 152: 128. 1924.
(492) WOLFF, E. Farm Foods. English Ed. Trans. by H. B. Cousins, Gurney and Jackson, London. 1895.
(493) Vermont Agr. Exp. Sta. Rpt. 1: 124. 1887.
(494) Vermont Agr. Exp. Sta. Rpt. 3: 71, 76. 1889.
(495) Vermont Agr. Exp. Sta. Rpt. 5: 86. 1891.
(496) Vermont Agr. Exp. Sta. Rpt. 7: 75, 79. 1893.
(497) Vermont Agr. Exp. Sta. Rpt. 10: 171. 1897.
(498) WALLIS, G. C. J. Agr. Res. 57: 393. 1938.
(499) ————————, AND T. M. OLSON. S. D. Agr. Exp. Sta. Bull. 321. 1938.
(500) ————————, L. S. PALMER, AND T. W. GULLICKSON. J. DAIRY SC. 18: 213. 1935.
(501) WATERS, H. J. Mo. Agr. Exp. Sta. Res. Bull. 19. 1915.
(502) WATSON, S. J. J. Agr. Sc. 21: 414. 1931.
(503) ————————. IIIrd Grassland Conference of the North Central European Countries in Switzerland. 1934.
(504) ————————. J. Roy. Agr. Soc. Eng. 95. 1934. (Reprint.)
(505) ————————. Silage and Crop Conservation. Macmillan and Co. Ltd. St. Marten's Street, London. 1938.
(506) ————————. Empire J. Expl. Agr. 7: 43. 1939.
(507) ————————, AND W. S. FERGUSON. J. Agr. Sc. 27: 67. 1937.
(508) ————————, ————————. J. Agr. Sc. 26: 189. 1936.
(509) ————————, ————————. J. Agr. Sc. 26: 337. 1936.
(510) ————————, ————————. J. Agr. Sc. 27: 1. 1937.
(511) ————————, ————————, AND E. A. HORTON. J. Agr. Sc. 27: 224. 1937.
(512) WEISKE, H. Landw. Vers. Sta. 48: 6: 379. 1897.
(513) WENDT, G. V. Z. Volkersernähr. Diätkost, 10: 116. 1935. Abstract Chem. Abs. 30: 5629. 1936.
(514) WESTGATE. Cited by C. V. Piper. Forage Plants and their Culture. The MacMillan Co. 1928.
(515) WESTOVER, H. L. J. Am. Soc. Agron. 26: 106. 1934.
(516) WHITE, G. C., AND R. E. JOHNSON. Conn. Agr. Exp. Sta. Bull. 198. 1934.
(517) WITSOE, J. A. Utah Agr. Exp. Sta. Bull. 48. 1897.
(518) ————————, AND J. STEWART. Utah Agr. Exp. Sta. Bull. 58. 1898.
(519) WIEGNER, G. Mitt. Dtsch. Landw. Ges. 40: 321. 1925. Cited by S. J. Watson, J. South-Eastern Jersey Club (Eng.) 1923. Reprint.
(520) WIGGANS, R. G. J. Am. Soc. Agron. 29: 456. 1937.
(521) WILLARD, H. S. Wyo. Agr. Exp. Sta. Bull. 199. 1933.
(522) ————————. Wyo. Agr. Exp. Sta. Bull. 202. 1934.
(523) ————————. J. DAIRY SC. 21: 153. 1938.

(524) WILLIAMS, R. D., AND W. H. OLMSTED. J. Nutrit. 11: 439. 1936.
(525) WILSON. Cited by P. F. Trowbridge, L. D. Haigh, and C. R. Moulton. Mo. Agr. Agr. Exp. Sta. Res. Bull. 20. 1915.
(526) WILSON, J. K. J. DAIRY SC. 18: 317. 1935.
(527) ———, AND H. J. WEBB. J. DAIRY SC. 20: 247. 1937.
(528) WING, H. H., AND L. ANDERSON. N. Y. (Cornell) Agr. Exp. Sta. Bull. 169. 1899.
(529) WISEMAN, H. G., E. A. KANE, L. A. SHINN, AND C. A. CARY. J. Agr. Res. 57: 635. 1938.
(530) WITHYCOMBE, J. Ore. Agr. Exp. Sta. Bull. 67. 1901.
(531) WOLL, F. W. Hoard's Dairyman 53: 321. 1917.
(532) ———. J. DAIRY SC. 1: 447. 1918.
(533) ———, AND G. C. HUMPHREY. Wis. Agr. Exp. Sta. 21st. Rpt. 67. 1904.
(534) ———, AND E. C. VOORHIES. Calif. Agr. Exp. Sta. Bull. 282. 1917.
(535) ———, ———, AND C. V. CASTLE. Calif. Agr. Exp. Sta. Bull. 323. 1920.
(536) WOODMAN, H. E. Biol. Rev. 5: 273. 1930.
(537) ———. J. Ministry Agr. 41: 1049. 1935.
(538) ———, AND A. AMOS. J. Agr. Sc. 14: 99. 1924.
(539) ———, J. W. BEE, AND G. GRIFFITH. J. Agr. Sc. 20: 53. 1930.
(540) ———, D. L. BLUNT, AND J. STEWART. J. Agr. Sc. 16: 205. 1926.
(541) ———, ———, ———. J. Agr. Sc. 17: 209. 1927.
(542) ———, AND A. EDEN. J. Agr. Sc. 25: 50. 1935.
(543) ———, AND R. E. EVANS. J. Agr. Sc. 20: 587. 1930.
(544) ———, ———. Nature 130: 1001. 1932.
(545) ———, ———. J. Agr. Sc. 23: 459. 1933.
(546) ———, ———. J. Agr. Sc. 28: 44. 1938.
(547) ———, ———, AND D. B. NORMAN. J. Agr. Sc. 23: 419. 1933.
(548) ———, ———, ———. J. Agr. Sc. 24: 283. 1934.
(549) ———, AND D. B. NORMAN. J. Agr. Sc. 22: 852. 1932.
(550) ———, ———, AND J. W. BEE. J. Agr. Sc. 18: 266. 1928.
(551) ———, ———, ———. J. Agr. Sc. 19: 236. 1929.
(552) ———, ———, AND M. H. FRENCH. J. Agr. Sc. 21: 267. 1931.
(553) ———, AND P. M. OOSTHUIZEN. J. Agr. Sc. 24: 574. 1934.
(554) WOODS, E., F. W. ATKESON, H. WELLHOUSEN, AND R. F. JOHNSON. J. DAIRY SC. 19: 581. 1936.
(555) WOODWARD, T. E. J. DAIRY SC. 19: 347. 1936.
(556) ———, AND J. B. SHEPHERD. U. S. D. A. Clip Sheet 949. 1936.
(557) ———, ———. J. DAIRY SC. 19: 697. 1936.
(558) ———, ———. U. S. D. A. Tech. Bull. 611. 1938.
(559) ———, ———, AND R. R. GRAVES. U. S. D. A. Misc. Pub. 130. 1932.
(560) WRIGHT, P. A., AND R. H. SHAW. J. Agr. Res. 32: 321. 1926.
(561) WYLIE, C. E., S. A. HINTON, AND J. W. WEAVER, JR. J. DAIRY SC. 21, No. 5: 102. 1938.
(562) WYLIE, C. E., AND L. R. NEAL. Tenn. Agr. Exp. Sta. Bull. 163. 1938.
(563) ZAGAMI, V. Atti. accod. Lincei 19: 186. 1934. Abstract in Chem. Abs. 28: 5102. 1934.
(564) ZSCHEYE. Vers. Deut. Zuckerindus. No. 703. II: 668. 1914. Abstract Exp. Sta. Record 32: 767. 1915.
(565) HENSON, E. R. Iowa Agr. Exp. Res. Bull. 251. 1939.

American Dairy Science Association Announcements

RESULTS OF ELECTION

The results of the election of officers on October 1, were as follows:

Vice-President: HARRY CAVE, Oklahoma A & M College, Stillwater, Okla.

Directors to serve for three years each:

C. N. SHEPARDSON, Texas A & M College, College Station, Tex.

FORDYCE ELY, University of Kentucky, Lexington, Ky.

ANNUAL MEETING—1940—AT PURDUE UNIVERSITY, LAFAYETTE, INDIANA, JUNE 24–27TH

We trust that you are now making plans to attend the annual meeting next June. Those members who will have papers to read should write to the Chairman of the Program Committee whose name will be announced at an early date and inform him that they are willing to present a paper.

At the 1939 meeting in Pullman, Wash., and Moscow, Idaho, the Secretary was authorized by the Board of Directors to canvas the heads of dairy departments throughout the country to ascertain whether or not they favored a change in time of holding the annual meeting. These returns are at present being received. The Secretary's office would also like to receive opinions from the membership at large. If you have any criticisms of the present time of holding the annual meeting or any ideas opposing alteration of the date, please address a letter containing your opinions to the Secretary, so that the Board may have a representative group of expressions of opinion to consider.

TWENTY-YEAR INDEX

At our last annual meeting the Board of Directors authorized the indexing of our first twenty volumes of the Journal. This should be published within the next twelve months.

In order to make your Journals of greatest value we recommend that you have them bound by volume. The first twenty-two volumes contain practically all of the research work done in the field of dairying.

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Ohio State University, Columbus, Ohio

ABSTRACTS OF LITERATURE

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Columbus, Ohio

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Prussian Dairy Research Institute, Kiel, Germany

State Agricultural Colleges and Experiment Stations

The Royal Technical College, Copenhagen, Denmark

United States Department of Agriculture

ABSTRACTS OF LITERATURE

BOOK REVIEWS

457. Rancidity in Edible Fats. C. A. LEA, 1939, Low Temperature Research Station, Cambridge. First American Edition. Published by: Chemical Publishing Company, Inc., New York, N. Y. 230 pages, $4.00.

The author defines rancidity as "a deterioration in odor and flavor which develops in fats or in fatty constituents of food stuffs on keeping," and thus includes in his discussion problems of absorption of odors by such foods as eggs, butter and meat.

The chemistry of fats and the chemical changes produced in them as they become rancid are treated on a broad basis of facts. The outstanding features of the book are: 1) The elucidation of the problem as a whole and the evaluation and interpretation of the work of the various research workers in the field; 2) The inclusion of methods in some detail for measuring the degree of rancidity and interpretations of the meaning and usefulness of the various tests; 3) An extensive bibliography, the chapter on Atmospheric Oxidation, for example, having 324 references; 4) A discussion of procedures to protect foods from rancidity. The book will be of great value to the research worker and all others who deal with the problem of food preservation in its various forms. J.F.L.

458. Butter. Fourth Edition. C. C. TOTMAN, the late G. L. MCKAY, AND C. LARSEN. John Wiley & Sons, Inc. 472 pages, illustrated, price $3.50.

This book, formerly entitled "Principles and Practice of Buttermaking" by McKay and Larsen, is designed primarily as a textbook for undergraduate instruction, dairy plant operators and others interested in dairying. The subject matter is presented in twenty-three chapters under the following chapter headings: History of Buttermaking; Composition and Properties of Milk and Cream; Milk and Its Products as Foods; Variation of Fat in Milk and Cream; Care of Milk and Cream on the Farm; Buying and Grading Cream; Neutralization; Pasteurization; Starters and Cream Ripening; Churning, Washing, Salting, and Working of Butter; Overrun; Defects in Butter: Their Causes and Prevention; Butter Marketing; Dairy Equipment: Metals, Depreciation, Care; Refrigeration; Washing Powders; Sanitation; Testing; Starting a Local Creamery; Standards and Definitions; Dairy Production and Statistics; Benefactors of the Dairy Industry, Dairy Associations, and Dairy Journals. The appendix contains a survey of the

cream grading laws of the United States, a discussion of butter classification and grades, rules, and regulations governing use of the Iowa butter trademark and the legal requirements of butter.

The buying and grading of cream, churning, working of butter and composition control and marketing are dealt with in considerable detail while related topics are treated in a more general way. Considerable material is presented in graphical form to facilitate instruction.

A list of selected references and questions covering the material presented in each chapter are helpful additions to the text. W.L.S.

459. Standard Chemical and Technical Dictionary. H. BENNETT. Chemical Publishing Co., Inc., New York, N. Y. 638 pages, price $10.00.

This work is a condensed technical word book bearing concise definitions rather than encyclopedic treatments. The coverage of industrial products, chemicals and trade names is complete. Abbreviations and contractions as well as symbols used in chemistry, mathematics, thermodynamics, pharmacy, etc., are given.

A special section on the nomenclature of organic compounds is included. The system of nomenclature followed throughout is based on the International Union Rules. The section on nomenclature is supplemented by the prefix names of the organic radicals.

This technical word book should prove very useful to students, writers, scientists and others who feel the need of keeping up to date with the many new technical words and expressions. T.S.S.

BACTERIOLOGY

460. Methods of Measuring Gas Production. L. A. ALLEN, Agricultural Bacteriology Department, Univ. of Reading, Reading, England. J. Dairy Res., *10:* 1–6, 1939.

An apparatus and methods are described for measuring gas production by microorganisms. Gas volume is calculated from the movement, due to the pressure of the developed gas, of a pellet of mercury in a calibrated capillary tube. Arrangements are described for both aerobic and anaerobic conditions. S.T.C.

461. Protein Metabolism and Acid Production by the Lactic Acid Bacteria in Milk. Influence of Yeast Extract and Chalk. M. BRAZ AND L. A. ALLEN, Agr. Bacteriology Dept., Univ. of Reading, Reading, England. J. Dairy Res., *10:* 20–34, 1939.

Streptococci and lactobacilli were grown in milk and in milk to which yeast extract, chalk or both was added. A study was made of acid production, viability, and effect on the protein in the milk on incubation at

20° C. The growth of streptococci or lactobacilli in milk resulted, with most species, in an increase of protein after several weeks' incubation. The proteose-peptone fraction showed a corresponding decrease. There was considerable proteolysis, however, in the milk used for cultures to which chalk was added. Much more acid was developed by the cultures in milk to which yeast extract was added. There was a decrease in the viability of the cultures (particularly of streptococci) grown in the milk to which yeast extract was added, presumably owing to the lethal effect of the extra acid produced, since when chalk was present the viability was not affected by yeast extract. S.T.C.

462. Gas Production by Bacterium Coli and by Lactic Acid Streptococci under Different Conditions. M. M. Hassouna and L. A. Allen, Agr. Bacteriology Dept., Univ. of Reading, Reading, England. J. Dairy Res., *10:* 7–19, 1939.

Using the capillary tube method of measuring gas evolved it was found that with vigorous strains of *Str. lactis* and of *Bact. coli* growing together in separated milk, when the inocula were respectively 1/10 and 1/1000 ml. (of a young milk culture in both cases) gas production by the latter organisms was inhibited by the former. In separated milk the gas evolved during the growth of *Bact. coli* was found to be carbon dioxide only. In dextrose or lactose broths under the same conditions, however, both hydrogen and carbon dioxide were formed. *Str. lactis, Str. cremoris* and *Str. paracitrovorus,* whether in pure or in mixed cultures, gave no evidence of gas formation by the capillary tube method in either separated milk, amounts were detected by the titration method, using large h tubes in which carbon dioxide was absorbed by alkali during growth. S.T.C.

463. The Part Played by Bacteria in the Reduction of Methylene Blue in Milk. Betty Constance Hobbs, Dept. of Bacteriology, London School of Hygiene and Tropical Medicine, London, England. J. Dairy Res., *10:* 35–58, 1939.

The author reports data showing that in any given sample of good quality raw milk one type of organism tends to assume predominance at the time of reduction of methylene blue. Members of the coliform group and *Staph. aureus* were among the commonest organisms present at the time of reduction. Various organisms isolated from milk at the time of reduction were examined for their rate of decolorization of methylene blue when growing in pure culture in "sterile" milk (freshly drawn from the healthy udder under aseptic conditions). The most rapidly reducing organisms belonged to the coliform group. Using a differential manometer the same organisms were tested for their power of absorbing oxygen when grown under highly aerobic conditions. With any given organism there was little

relationship between the rate of oxygen absorption and the rate of methylene blue reduction. The author's data taken in conjunction with those of other workers shows a fairly high correlation between the rate of fall in the oxidation-reduction potential of the culture and the rapidity with which methylene blue is reduced. The mechanism by which methylene blue is reduced in milk by actively growing bacteria is discussed in some detail. The author believes that reduction is primarily a result of the metabolic reactions proceeding at the cell surface of the bacteria themselves, and consequently that the methylene blue reduction test affords a good index of the extent of bacterial metabolism in the milk. S.T.C.

464. Sur les Alterations Acidogènes du Lait. (On the Changes Produced in Milk by Acid-Producing Bacteria.) A. FOURNIER. Le Lait, *19:* 575–585, 1939.

An attempt is made to assess the ability of fecal bacteria to ferment the lactose of milk and to compare their rate of acid production with that of true lactic acid organisms. Where milk samples were inoculated and held at 20° and 37° C. both types produced acid with equal speed. The amount of inoculum was without effect. Samples were also held at −15° for 10 hours and at 60, 80, 100 and 105° C. for 30, 20, 15 and 10 minutes respectively, but with no increase in lactic acid occurring. O.R.I.

CHEESE

465. Starter Cultures for Cheese Manufacture. Maintenance of Acid-producing Activity in Cultures of Lactic Streptococci. H. R. WHITEHEAD AND G. J. E. HUNTER, Dairy Research Institute (N. Z.), Palmerston North, New Zealand. J. Dairy Res., *10:* 120–132, 1939.

Heavy inoculation (1.0–1.6 instead of the usual 0.2 per cent) was found effective in preventing starter failure due to bacteriophage. The authors postulate that the effect of heavy inoculation in eliminating the spontaneous appearance of bacteriophage is due to the more rapid growth of the streptococci when they are transferred to the new batch of milk; *i.e.* to the shortening of the lag period. S.T.C.

466. The White Particles in Mature Cheddar Cheese. F. H. MCDOWALL AND A. K. R. MCDOWELL, Dairy Research Institute (N. Z.), Palmerston North, New Zealand. J. Dairy Res., *10:* 118–119, 1939.

A sufficient quantity of the white particles for chemical analysis were picked out by hand from a mature cheese. The white specks were shown to be calcium lactate. S.T.C.

CHEMISTRY

467. Séparation du Lactose et des Proteines Solubles Contenues dans le Sérum du Lait par Extraction par L'alcool. (Separation of the Lactose and of the Soluble Proteins of Whey by Extraction with Alcohol.) G. GENIN. Le Lait, *19:* 693–698, 1939.

Two variations of an alcohol-extracting method for the separation of lactose from spray-dried whey powder are described. First, the whey powder is mixed with 70.7 per cent alcohol. Water and 95 per cent alcohol are then added at the rate of one part water to four parts alcohol. From the acidified filtrate obtained, a good yield of high quality lactose can be secured.

A more rapid method consists of the use of 95 per cent alcohol at a temperature of 60° C. for two hours. A lower yield of lactose is obtained by this method. The first method described requires an extraction period of 15 hours. O.R.I.

CONCENTRATED AND DRY MILK; BY-PRODUCTS

468. Sanitary Control of Dried Milk. PAUL S. PRICKETT, Mead Johnson and Co., Evansville, Ind. J. of Milk Techn., *2:* 133–137, 1939.

Some of the more important bacteriological procedures which may be applied to the sanitary control of this product are discussed. L.H.B.

469. Laits Dilués, Laits Concentrés, Lait Desséchés. Considérations sur le Problème de la Concentration la plus Convenable du Lait dans les Aliments Lactés Infantile. (Diluted Milks, Concentrated Milks, Dried Milks. Consideration of the Problem of the Most Suitable Concentration of Milk in Infant Milk Foods.) L. PIKLER. Le Lait, *19:* 561–573, 1939.

In this review the question of using concentrated milks for infant feeding is studied from several unusual angles such as the effect of changes in the solids concentration upon colloid structure, salt balance, osmotic pressure, protein solubility, etc. No experimental evidence is presented to show that these changes affect the nutritional properties of concentrated milks. O.R.I.

DISEASE

470. Studies in Mastitis. I. The Routine Diagnosis of Mastitis. J. G. DAVIS, J. MCCLEMONT, AND H. G. ROGERS, National Institute for Research in Dairying, Univ. of Reading, Shinfield, near Reading, England. J. Dairy Res., *10:* 59–73, 1939.

Methods of taking and examining samples of milk for *Str. agalactiae*

are described. Where the samples can be examined within a few hours the authors prefer plain blood agar. Edward's medium is recommended where delay in examination is unavoidable. Cultural confirmation of suspected colonies is considered to be imperative. A test for the hydrolysis of hippurate which is said to be the most specific biochemical characteristic of *Str. agalactiae* is described. S.T.C.

471. **Studies in Mastitis. II. A Comparison of Methods for the Detection of Subclinical Mastitis.** J. G. DAVIS AND J. MCCLEMONT, National Institute for Research in Dairying, Univ. of Reading, Shinfield, near Reading, England. J. Dairy Res., *10:* 74–80, 1939.

Using the results obtained by plating the milk twice in Edward's medium as a criterion, the following were compared:

1. Plating the deposit from 10 ml. of milk in the same medium.
2. Direct plating of milk in Edward's medium without blood.
3. Direct plating of milk in blood agar.
4. Direct plating of milk in milk agar.
5. Methylene blue reduction test.
6. Catalase test.
7. Rennet test.
8. "Growth of starter" test.
9. Brom-cresol-purple paper test.
10. Incubation test (with addition of litmus solution).
11. Titratable acidity test.
12. Clinical examination.

The authors consider the brom-cresol-purple paper, strip cup and induration tests to be worth doing in order to get a general idea of the incidence of mastitis in the herd. All of the simple tests had roughly the same order of efficiency in that they detected about half the positive cases and gave 10–30 per cent false positives. S.T.C.

472. **Studies in Mastitis. III. Mastitis in Relation to "Udder" Counts.** J. MCCLEMONT AND J. G. DAVIS, National Institute for Research in Dairying, Univ. of Reading, Shinfield, near Reading, England. J. Dairy Res., *10:* 81–87, 1939.

Mastitis was found to have a marked effect on the "udder count" as given by the total colony count on milk agar. Samples for the "udder counts" were taken after about ½ pint of milk had been removed from each quarter. No samples from mastitis-free cows were found to have a count of over 2000 per ml. and very few over 500. About 50 per cent of infected cows yielded milk with a count of over 1000. The authors state that a count of under 100 per ml. may be taken to indicate freedom from infection and a count of over 1000 to indicate mastitis. S.T.C.

473. Studies on Mastitis. IV. Mastitis in Relation to the Methylene Blue Reduction Test. J. McClemont and J. G. Davis, National Institute for Research in Dairying, Univ. of Reading, Shinfield, near Reading, England. J. Dairy Res., *10:* 88–93, 1939.

A systematic investigation of a number of strains of *Str. agalactiae* in milk containing varying concentrations of methylene blue was made. The results confirm previous findings that *Str. agalactiae* either does not reduce methylene blue or does so with difficulty. In testing 156 moderately and severely infected cows only thirty-six gave a short reduction time (9 hr.). Of 252 samples free from infection, twelve gave a false positive reaction. It is concluded that while some cases of mastitis lower the reduction time, the test is of no use for the detection of mastitis. Storage of the samples for 16 hours, either at 4 or 15.5° C., did not materially improve the efficiency of the test. S.T.C.

474. The Value of Indirect Methods for the Detection of Mastitis. S. J. Rowland and M. Zein-el-dine, Dept. of Agricultural Chemistry, Univ. of Reading, Reading, England. J. Dairy Res., *10:* 108–113, 1939.

Using the mean square contingency as a measure of agreement with the direct bacteriological method, indirect methods for the detection of subclinical mastitis were placed in the descending order of their value for diagnosis thus: casein number, chloride content, centrifuge deposit, solids-not-fat content, brom-cresol-purple reaction, brom-thymol-blue reaction, presence of clots, catalase content. S.T.C.

475. Studies in Mastitis. VI. General Observations, Summary and Conclusions. J. G. Davis and J. McClemont, National Institute for Research in Dairying, Univ. of Reading, Shinfield, near Reading, England. J. Dairy Res., *10:* 104–107, 1939.

The incidence of mastitis was found to increase steadily with age of the animal. The authors stress that for eradication purpose there are only two methods of diagnosis worth using—simple tests on the farm and carefully controlled bacteriological examination in the laboratory. S.T.C.

476. Studies in Mastitis. V. Mastitis in Relation to Cheese-making. J. G. Davis and J. McClemont, National Institute for Research in Dairying, Univ. of Reading, Shinfield, near Reading, England. J. Dairy Res., *10:* 94–103, 1939.

A test (brom-cresol-purple-rennet) based on the time of coagulation with rennet, reaction with brom-cresol-purple and type and appearance of curd after incubation for 16 hours at 37° C., is described and recommended as a

general test for mastitis and suitability of the milk for cheesemaking. Milk, abnormal due to mastitis, was found to yield cheese of appreciably weaker body (lower viscosity). Many samples of mastitis milk were found to give slow growth of starter. S.T.C.

477. Infectious Bovine Mastitis. 7. Characteristics of Udder Staphylococci. W. N. PLASTRIDGE, E. O. ANDERSON, L. F. WILLIAMS AND F. J. WEIRETHER. Storrs Agr. Exp. Sta. Bull. 231, 1939.

Staphylococcal mastitis is usually milder in character, and incidence of recovery is greater than with Streptococcal mastitis. The source of *Str. agalactiae* appears to be limited to the infected bovine udder, whereas the source of pathogenic udder staphylococci is apparently not limited to the infected udder.

The following properties did not appear satisfactory for determining the relative irritating ability of a given culture: pigment formation, effect on litmus milk, ability to ferment certain carbohydrates and to liquify gelatin and behavior on alkaline bromthymol-blue lactose agar and Bacto crystal violet agar. However, in general, cultures associated with a high degree of irritation in the bovine udder were more active in laboratory media than were cultures associated with a low degree of irritation.

The ability of recently isolated udder staphylococci to coagulate human plasma was found to be more closely related to irritating ability than any other property.

The average leucocyte count of 2,125 "normal" samples was found to be 73,000 per cc. and the chloride content was 0.121 per cent.

The average leucocyte content of samples of milk containing non-hemolytic, weakly hemolytic and hemolytic staphylococci was 220,000, 1,020,000 and 1,361,000 per cc. respectively. The average chloride content of same samples for nonhemolytic, weakly hemolytic and hemolytic staphylococci was 0.118, 0.141, and 0.151 per cent respectively.

In the routine examination of milk, udder staphylococci which produce hemolytic colonies on cows' blood agar or which are associated with leucocyte counts of 500,000 or more per cc. may be considered as probably pathogenic, providing that high leucocyte counts resulting from early or late lactation are excluded.

The practical consideration of the possibility of food poisoning from milk is discussed. E.O.A.

478. A Further Study of the Production of Milk of Abnormal Composition by Cows Free from Udder Streptococci. E. G. HASTINGS AND B. A. BEACH, Wis. Agr. Exp. Sta. J. Agr. Res., *58:* 7, 543–556, April 1, 1939.

The foremilks of 12 of 31 cows previously studied throughout their first lactations (J. Agr. Res. 54: 199–220, 1937) were examined periodically

during their second lactations for chlorides and catalase, using the first 30 cc. from each quarter as sample. At less frequent intervals the remainder of the milk from each quarter was examined in greater detail. Disturbances noted in the foremilk during the first lactation were observed also during the second lactation. This continued study did not reveal the cause of the disturbance or the transmissibility of its cause. Abnormal milks produced without apparent bacterial cause were noted and the authors believe that the environment provided in the abnormal quarters is more favorable for the establishment of streptococci than that provided by the normal gland. Milk from disturbed quarters was rarely so changed in composition as to be of less value either as fluid milk or as a raw material for milk products than normal milk. L.M.T.

479. Report of the Committee on Communicable Diseases Affecting Man. I. A. MERCHANT, Iowa State College, Ames, Iowa. J. of Milk Techn., *2:* 110–117, 1939.

There were 43 milk-borne epidemics reported in the United States and 13 reported in Canada during 1937.

The origin of 18 of the epidemics in the United States was traced to carriers. Raw sweet milk was involved in the majority of cases. Where pasteurized milk was involved, investigation showed that the process was faulty or the milk was contaminated after pasteurization.

A number of epidemics, all of which were gastrointestinal in nature were traced to milk products (cheese and homemade ice cream).

From 1923 through 1937 there have been a total of 653 milk-borne epidemics reported in the United States.

In order to inform milk handlers of effective methods in preventing diseases being spread by milk, the Connecticut State Department of Health has published a pamphlet which has been distributed to dairymen. A copy of this pamphlet is made a part of this report. L.H.B.

480. The Relation of Streptococcic Mastitis to Certain Phases of Milk Sanitation. C. S. BRYAN, Mich. Agr. Exp. Sta., East Lansing, Mich. J. of Milk Techn., *2:* 32–40, 1939.

Physical examination of the udder is of great value in detecting streptococcic mastitis, but is not as reliable as the microscopic test.

The microscopic test is based upon the continued presence of streptococci of more than six organisms per chain in milk of infected cows. The milk must be properly collected and incubated at 37° C. for at least 12 hours before examining under the microscope.

This test was more efficient than seven other tests commonly used for detecting mastitis.

The city of Lansing, Michigan, requires Grade A raw milk to be pro-

duced from cows that are free of tuberculosis, Bang's disease, and streptococcic mastitis. L.H.B.

FEEDS AND FEEDING

481. Feeding Grass Silage to the Dairy Cow. H. S. Wright, Sheffield Farms Company, Pawling, N. Y. Cert. Milk, *14:* 155, 8, 1939.

The author concludes that the molasses ensilage method of crop preservation merits a part in the Sheffield Farms feeding plan when applied:

1. Through the medium of lower protein roughages fed to the dry cow and young stock.

2. Through the higher protein, better milk making roughages in the ration of the milking cow, in combination with hay and concentrates in amounts necessary to furnish the food requirements. W.S.M.

FOOD VALUE OF DAIRY PRODUCTS

482. The Effect of Churning on the Vitamin A and Carotene Content of Milk Fat. K. M. Henry and S. K. Kon, National Institute for Research in Dairying, Univ. of Reading, Shinfield, near Reading, England; A. E. Gillam, Chemistry Dept., Victoria Univ., Manchester, England, and P. White, Univ. of Reading, Reading, England. J. Dairy Res., *10:* 114–117, 1939.

The vitamin A and carotene content of 14 samples of butterfat secured by churning and by ether extraction from the same milks were determined by spectrophotometric methods and by Lovibond tintometer tests. Assuming that there is no loss of either carotene or vitamin A in the course of the ether extraction, their data indicates that there is some loss of carotene in churning but that vitamin A is not appreciably affected. S.T.C.

483. De la Vitamine A et du Carotene dans la Conservation du Lait et la Creme sous Pression D'oxygène Élevée (Procédé Hofius). (Studies on the Vitamin A and Carotene in Milk and Cream Preserved by Increased Oxygen Pressure. (Hofius Process.).) E. Brouwer, E. A. M. Meyknecht and N. D. Dijkstra. Le Lait, *19:* 673–686, 1939.

Samples of milk and cream held for one to three months under about ten atmospheres pressure and at 4–6° C. showed no significant loss of vitamin A or Carotene. Analyses were made by spectrophotometer and in five of the nine experiments by rat assays. Both raw and pasteurized products were studied. In one experiment the temperature of holding was raised to 19° C. without increasing the rate of destruction of vitamin A or its precursor. O.R.I.

484. Le Taux de L'acide Ascorbique dans de Lait de Quelques Mammifères. (The Ascorbic Acid Content of the Milk of Some Mammals.) L. BURIANA, Le Lait, *19:* 449–455, 1939.

Recent literature is reviewed to show that there is some disagreement regarding the ascorbic acid content of the milk of different species and especially during the secretion of colostrum. As a result of recent studies the authors contend that the method of Martini and Bonsignore (Biochem. Z. *273*: 170, 1934) based on the reduction of methylene blue is a more accurate quantitative method than the one utilizing 2-6-dichlorophenol-indophenol.

Human milk, analyzed by this method was shown to be very poor in ascorbic acid. Values obtained from several analyses averaged around 3 mgm. per liter whereas the same samples analyzed by the 2-6-dichlorophenol-indophenol method gave values varying between 30–50 mgm. per liter. The values found for mares', asses', and sows' milks were all extremely high. Cows' milks varied between 50–70 mgm. per liter when analyzed by the methylene blue method. O.R.I.

485. Influence des Manipulation et de la Température de Conservation sur le Contenu en Vitamine C du Lait Destiné a L'alimentation Humaine. (The Effect of Handling and of Holding Temperature on the Vitamin C Content of Milk Destined for Human Consumption.) G. FAILLA, Le Lait., *19:* 455–461, 1939.

Using Sharp's method of determining vitamin C with 2-6-dichlorophenol-indophenol, the author found most samples of commercial pasteurized milks were much lower in this vitamin than was the raw milk of the University of Milan herd. A study of the factors suspected of causing this difference revealed that:

(1) Vitamin C is oxidized to marked degree in raw milk. This is particularly true where the raw milk is not held at a low temperature.

(2) Oxidation takes place at a greatly reduced rate in pasteurized milk.

It is suggested that pasteurization destroys the peroxidase enzyme which is the agent causing rapid oxidation of the vitamin. O.R.I.

486. Factors Affecting the Vitamin C Content of Milk. MYER GLICKSTEIN AND J. H. FRANDSEN, Mass. State College, Amherst, Mass. Milk Dealer, *28:* 11, 42–46, Aug., 1939.

A review of the literature dealing with effect of stage of lactation, breed, ration, miscellaneous factors, and commercial practices on the vitamin C content of milk. C.J.B.

HERD MANAGEMENT

487. Lower Production Costs a Vital Factor. H. B. ELLENBERGER, Univ. of Vermont, Burlington, Vt. Assoc. Bull., Intern. Assoc. Milk Dealers, *10:* 1, 22, Dec. 20, 1938.

Rather than to depend upon higher prices of milk to furnish a profit it would produce satisfactory results more surely to apply known methods of reducing the cost of producing 100 pounds of milk on the farm by employing already known selection breeding and feeding methods. At least 7,000 to 8,000 pounds of average test milk per cow should be sought. Generous use of good quality grass and hay provide much cheaper feed costs per 100 pounds than too heavy grain feeding. It is stated that the feed cost of producing milk with poor roughage is 25 per cent to 30 per cent higher than with good roughage. E.F.G.

488. Problems in Growing Herd Replacements. G. E. TAYLOR, New Jersey Agr. Exp. Sta., New Brunswick, N. J. Part I, Cert. Milk, *14:* 158, 7, 1939; Part II, Cert. Milk, *14:* 159, 11, 1939.

Herd health and disease control is one of the major problems confronting the owner of livestock. As a disease preventive measure it is suggested that dairy farmers adopt a practice of growing heifers that are needed for replacement purposes. The problems encountered in growing herd replacements are discussed, beginning with a calf at time of birth and following through with recommended practices leading up to the time the heifer comes into production. W.S.M.

ICE CREAM

489. Condensed and Evaporated milk with Reference to Ice Cream. P. A. DOWNS, Univ. of Nebr., Lincoln, Nebr. J. of Milk Techn., *2:* 130–132, 1939.

Evaporated milk, which is sterilized, presents no bacteriological problem to the ice cream manufacturer if used as soon as the cans are opened.

Sweetened condensed, either skim or whole if it contains 72 to 74 per cent total solids, presents no problem either. However, when modifications are used so that there isn't sufficient sugar present to make a saturated solution of the water left in the product then the product must be so handled to prevent bacterial growth. Usually this product is frozen solid and stored at such temperature to prevent thawing until ready for use.

Plain condensed and super-heated condensed milk must also be handled in this way.

Care must be exercised in thawing these products before use so as to prevent contamination and increase in bacterial numbers. L.H.B.

490. Public Health and Aspects of Fruits, Nuts, Colors, and Extracts in Frozen Desserts. M. J. PRUCHA, Univ. of Ill., Urbana, Ill. J. of Milk Techn., *2:* 127–129, 1939.

Bacteriological examinations were made of a considerable number (207)

of samples of ingredients used in ice cream, such as flavoring extracts, fruits, nuts, and color solutions. Results showed that 164 samples contained bacteria of various kinds, 24 samples had an abundance of coliform bacteria present, and 107 samples contained yeasts and molds.

A study of the bacteriological condition of these various ingredients made at two different plants, one where the ingredients were properly cared for and the other where no care was given, showed that proper care of the ingredients was a big factor in maintaining not only a lower total bacterial content, but no yeasts and molds were present, and very few coliform organisms. L.H.B.

491. Sanitation of Products Added to Frozen Desserts. P. H. TRACY, Univ. of Ill., Urbana, Ill. J. of Milk Techn., *2:* 118–126, 1939.

More attention should be given by the dairy plant operator in preparing and caring for flavoring and coloring materials used in ice cream. By so doing the sanitary qualities of the ice cream will be improved.

Methods of preparation and precautions to be used for fruits, nut meats, coloring material and flavoring extracts are given.

Certain fruits and extracts will withstand heating to 145° F. for 30 minutes without serious injury to the flavor.

Nut meats should be dipped in boiling sugar solution (50 per cent), to which one per cent salt has been added, for 15 seconds, and then dried in an oven for 2.5 minutes at 250° C. L.H.B.

492. Sediment Tests on Frozen Desserts. M. E. PARKER, Beatrice Creamery Co., Chicago, Ill. J. of Milk Techn., *2:* 87–90, 1939.

It is suggested that the sediment test on ice cream be made on a half pint sample of mix or a pint sample of the frozen ice cream.

The same sediment standards which are used for milk may be applied to frozen desserts.

References as to methods for determining the amount of sediment in various products used in making ice cream mix are given. L.H.B.

493. Notes on Microbiological Analysis of Ice Cream. A. H. ROBERTSON, State Food Laboratory, Albany, N. Y. J. of Milk Techn., *2:* 84–86, 1939.

Methods of taking samples and making bacterial counts on ice cream are discussed. L.H.B.

494. What Are Frozen Desserts? F. W. FABIAN, Mich. State College, East Lansing, Mich. J. of Milk Techn., *2:* 75–83, 1939

General definitions of various frozen desserts are given. Inconsistencies of legal definitions are cited. There is a wide variation in the range of minimum legal requirements of chemical composition of frozen desserts.

Sanitary requirements have been slow in coming but are on their way. In 1926 no state had a bacterial standard while now 12 states have a minimum bacterial standard for ice cream ranging from 75,000 to 500,000 per gram.

A standard of not more than 100,000 bacteria per gram should be established as should a pasteurizing temperature of 150° F. for 30 minutes.

The problem of what to do about frosted malted milk is discussed but no solution is given. L.H.B.

495. Weight and Overrun. M. C. VARNEY, Engineer, Exact Weight Scale Co., Columbus, Ohio. Ice Cream Field, *34:* 2, 42, Aug., 1939.

A description of a scale suitable for determining overrun in ice cream and ices is described, and the relation between overrun and density illustrated. W.C.C.

496. Refrigerated Truck Bodies. H. H. HARRINGTON AND L. M. S. COOPER, Transportation Dept., General Electric Co., Erie, Pa. Ice Cream Field, *34:* 2, 12–14, 43–47, Aug., 1939.

This is a fairly complete report with recommendations for design and construction of refrigerated truck bodies suitable for ice cream. The various phases are well illustrated with pictures or schematic diagrams.

According to the report there is a demand for the following type of refrigeration equipment.

1. Automatic. Direct expansion evaporator with condensing unit having electric motor for plug-in power and power take-off drive. For service requiring unlimited operating time and with the truck engine running equivalent to at least 10 miles per hour of elapsed time.

2. Automatic with partial hold-over including condensing unit, a-c motor for plug-in power and PTO drive. For service requiring unlimited operating time and with the truck engine running equivalent to an average of 6 miles per hour of elapsed time. This system is especially well suited to mixed interurban and city service.

3. Hold-over with condensing unit and motor for plug-in power. For frequent stop, city service and low daily mileage. The time away from the plant is limited by the thermal capacity of the hold-over cooling units.

4. Hold-over for plant refrigeration. This system is preferred by operators using a large number of trucks operating from a central plant in which a large ammonia refrigeration system is available. For service similar to No. 3, except that facilities for recharging are limited to the ammonia plant.

The normal insulation thickness recommended is 6 inches except on the roof crown where it is 8 inches. On this basis and with the design of equipment proposed the insulation occupies approximately 40 per cent of the total body volume leaving 60 per cent for useful load.

With this relatively large insulation volume it is advisable to select insulation with low specific weight. Using glass wool and thermocraft the total body insulation equals 400 pounds, if cork were used the insulation weight would be approximately 1400 pounds.

Although color and sign painting are generally specified by the operator it is advisable to use light colors and it is especially desirable to have the roof painted aluminum as a means of decreasing solar heat absorption.

It is pointed out that to obtain the maximum effectiveness of the hold-over cooling unit, especially in extremely warm weather, it is advisable to scrape the bottom surface of the tank daily, particularly when the humidity is high.

Methods of arriving at required compressor capacities as well as costs of operation under various conditions are illustrated by calculated example.

W.C.C.

MILK

497. Factors Influencing the Reduction of Methylene Blue in Milk. C. K. JOHNS, Central Exp. Farms, Ottawa, Can. Sc. Agr., *21:* 435–457, 1939.

This paper is a comprehensive report on the effect of variations in methods upon methylene blue reduction time. An incubation temperature of 37.5° C. was found to be just as satisfactory as any other. Inversion of the tubes at two hour intervals increased the reliability of the test. More frequent inversion was not advantageous. Increasing the concentration of the dye to 1:300,000 resulted in a 20 per cent longer reduction time.

A preliminary incubation period of 18 hours at 12.8° C. was shown to improve the test as an index of keeping quality. Fresh milk possesses a bacteriostatic principle which inhibits the multiplication of bacteria and reduction of the dye. The use of the incubation period at 12.8° C. lessens the effect of this principle and permits closer grading of the milk. O.R.I.

498. Factors Affecting the Composition of Milk. D. H. JACOBSEN AND G. C. WALLIS. South Dakota Bull. 331, 1939.

Analyses of milk from cows of the College herd were made monthly over a 5-year period. The milk from Holstein, Guernsey, Jersey and Ayrshire cows was analyzed for fat, total solids, ash, calcium and phosphorus. The influence of breed, stage of lactation, and season was studied.

Fat tests in general decreased to the end of the third month and then increased with the advance in lactation. Jersey and Guernsey milk tested highest near the end of the lactation; Holstein milk tested highest at the beginning of the lactation.

Total solids analyses showed Holstein milk tested highest at the beginning of the lactation.

Total solids analyses showed Holstein milk to average 10 to 11 per cent, Guernsey about 14 per cent and Jersey 14 to 15 per cent.

Holstein milk showed greater tendency to be sub-legal in solids-not-fat than in fat; the former being below standard throughout the year.

Calcium and phosphorus decreased the first month and increased during the last 3 months of lactation.

Colostrum milk was also analyzed. It is suggested that low testing milk can be avoided by: (1) selecting cows for high test (2) balancing freshening dates during the year (3) standardizing low-test with high-test milk.

C.C.T.

499. Why Sales Contests? R. G. PEAT, Silverwood Dairies, Ltd., Hamilton, Ont. Assoc. Bull., Intern. Assoc. Milk Dealers, 31st Year, *4:* 89, February 13, 1939.

A great value of sales contests is that they break the regular routine and lift salesmen out of a rut. The spirit of competition properly developed by suitable incentives, the strongest of which are frequently not money, will improve the salesman's approach to the customer. Sales contests return a profit to the company.

E.F.G.

500. What Consumers Think of the Milk Dealer. PAUL POTTER, Associated Milk Dealers, Inc., Chicago, Ill. Assoc. Bull., Intern. Assoc. Milk Dealers, 31st Year, *4:* 84, February 13, 1939.

The Business Research Corporation of Chicago carefully sampled the Chicago milk market through 1938 personal interviews with housewives and 350 interviews with retail grocers.

Some of the conclusion are:

1. Losses in volume by the dealers are due more to depression, reduced prices on other foods and cut-rate competition than to dissatisfaction with the product or to any change in attitude toward the use of milk or to the dealers selling it.

2. The public wants both the home wagon delivery service and the neighborhood store distribution.

3. That the storekeepers are satisfied to handle milk as a convenience on a minimum profit margin and that this is a highly desirable situation for the public and for the milk dealer.

4. The belief that selling through stores increases the per capita consumption is based upon experiences in which the price differential between the wagon price and the store price was a great deal more than 1 cent per quart.

5. The situation calls for careful examination of possible ways of reducing wastes in production processing and distribution methods and the

possibility of wage adjustments based upon what the public will pay as well as what the wage earner wants.

6. There is a need for a better understanding of the food value of milk, and a need for more and better reminders as to how and when to use it.

7. The value of the good will built up over the years by good products and good services warrants extraordinary efforts to preserve it. E.F.G.

501. Guide Posts for Hiring Route Salesmen. MARLYN A. SMULL, Univ. of Tenn., Knoxville, Tenn. Assoc. Bull., Intern. Assoc. Milk Dealers, 31st Year, *4:* 77, February 13, 1939.

Since the cost of training route salesmen is considerable there is need for a sound method of selecting the most promising men for this work.

Thirty-two definable personal differences among milk salesmen were classified by 16 milk sales executives from standpoint of their relative importance for sales success. Adaptability was considered the most desirable quality. Fifty route salesmen were rated on desirable characteristics by means of a rating scale and their score compared with their sales record. The validity of the characteristics for sales work was demonstrated. The order of importance of the characteristics is as follows: 1. Adaptability; 2. Alertness; 3. Business-likeness; 4. Originality; 5. Initiative; 6. Drive; 7. Judgment; 8. Self confidence; 9. Tact; 10. Patience.

The author suggests a questionnaire which could be answered in 30 minutes which would enable the employer to rate salesmen on the above characteristics. E.F.G.

502. A Study of Pasteurized Milk in Rochester, N. Y., Employing the Phosphatase Test. HAROLD W. LEAHY, Health Bureau Laboratories, Rochester, N. Y. J. of Milk Techn., *2:* 147–151, 1939.

The phosphatase test used consisted of adding 1.0 cc. of milk to 10.0 cc. of Kay and Graham's buffered substrate solution and incubating for 18 hours at 37° C. Then 0.2 cc. of a 0.4 per cent solution of BQC was added to determine the presence of phenol.

Three standards were used for determining the degree of pasteurization. These were made by adding 0.01 mg., 0.05 mg. and 0.10 mg. of phenol, respectively, to pasteurized milk.

Milk producing 0.01 mg. or less of phenol was interpreted as "properly pasteurized"; between 0.01 and 0.05 mg. as "slightly underpasteurized," and between 0.05 mg. and 0.10 mg. as "underpasteurizerd." Those which produced greater amounts than that were definitely "underpasteurized."

Using this method in the course of a year's study of 104 pasteurizing plants in Rochester, New York, 50 plants were observed whose milk never gave evidence of improper pasteurization. Twenty-one plants were found

with occasional minor imperfections, and routine phosphatase tests were rarely positive. The remainder frequently showed evidence of faulty operation; nine of these on inspection showed multiple faults. L.H.B.

503. Latest Developments in Cooling Milk on the Dairy Farm. JOHN E. NICHOLAS, Pennsylvania State College, State College, Pa. J. of Milk Techn., *2:* 141–146, 1939.

Four types of modern mechanical milk coolers are illustrated and described. They are either of the type spraying cold water around the neck of the can or the can is submerged to the neck in cold water. In all cases the water is agitated during the cooling process.

When the initial temperature of the cooling water was 36.5° F. and the initial temperature of the milk was 90° F. and there was 3.5 gallons of water for each gallon of milk cooled, the temperature of the milk at the top of the can at the end of one hour was 53° F. and at the bottom of the can was 46.5° F. The temperature of the water at the end of 1¼ hours when agitation was stopped was 46.5° F. L.H.B.

504. Report of the Committee on Dairy Farm Methods, 1938. F. D. HOLFORD, Borden Farm Products Co., New York City. J. of Milk Techn., *2:* 138–140, 1939.

This report deals almost entirely with the cleaning and care of milking machines.

It is not necessary to take machines apart after each milking. Taking apart once a week to prevent the rubber tubing from sticking to the metal parts is sufficient. Check valves, vacuum lines, etc. should be cleaned regularly.

Two methods are recommended, No. 1–Cold and hot water (180° F.) are drawn through by suction immediately after milking. Then protect the units by storing in a dry place or in clean cold water, brine or chlorine solution until the next milking. Use a solution rack.

No. 2–Cold water and lye solution. Cold water is drawn through the units with vacuum; the long milk tube and teat cups are then hung on a solution rack and filled with a weak solution of lye. (This method should not be used on milking machines having aluminum parts as lye corrodes aluminum.) L.H.B.

505. Reduction of Milk Losses in Milk Plants. A. C. DAHLBERG, J. C. HENING, AND H. L. DURHAM, New York Agr. Exp. Sta., Geneva, N. Y. J. of Milk Techn., *2:* 96–99, 1939.

See abstract 520 this issue.

506. Engineering Problems in Milk Sanitation. LESLIE C. FRANK, U. S. Public Health Service, Washington, D. C. J. of Milk Techn., *2:* 58–72, 1939.

Milk sanitation is a problem which requires the serious attention of sanitary engineers as well as of bacteriologists, veterinarians, and epidemiologists.

In addition to the problems of pasteurization the sanitary engineer should give attention to the following problems:

1. Dairy barn and milk house design.
2. Dairy farm water supplies.
3. Disposal of excreta on the farm.
4. Pasteurization plant design.
5. Water supplies.
6. Plumbing.
7. Excreta and waste disposal.
8. Special problems relating to pasteurization equipment, operation and design to insure every particle of milk being properly pasteurized. Regenerators, leak protector valves, air space heaters, automatic controls, etc.

L.H.B.

507. The Practical Application of the Phosphatase Test. D. M. ROGER, The Borden Farm Products Co., Brooklyn, N. Y. J. of Milk Techn., *2:* 21–25, 1939.

Scharer's rapid field test or slight modification of it was found reliable when properly used. More than 18,000 tests were made during the past year in the Borden plants.

No cases of interfering substances in milk have been found.

Modifications generally used were to substitute amyl alcohol in place of butyl, and to increase the incubation time to 30 min. in place of 10 min.

Amyl alcohol has the advantage of not extracting so much of the yellow color from high color milk and cream.

Increasing the incubation time made the test more sensitive.

Some causes of high phosphatase tests found are given. L.H.B.

508. Homogenized Milk. C. J. BABCOCK, Bureau of Dairy Ind., Dept. of Agr., Washington, D. C. J. of Milk Techn., *2:* 26–31, 1939.

Homogenized milk is on the increase. According to a questionnaire sent out by the Bureau of Dairy Industry to milk plants all over the United States, 260 replies have been received. Of these 30 reported that they were featuring homogenized milk, and 23 of them reported that the sale of homogenized milk was increasing.

Homogenized milk, pasteurized at 143° F. for 30 minutes, at 2500 lbs. pressure the average curd tension was reduced to 16.7 gr. as compared to an average curd tension of 50.2 gr. for the raw milk.

Digestion studies made of raw milk, milk boiled for five minutes, and pasteurized milk, homogenized at 2500 lbs. pressure, showed that the boiled

and homogenized milk digested more rapidly but not any more completely than the raw milk. The boiled milk digested slightly more rapidly than did the homogenized. These tests were made in vitro. L.H.B.

509. Application of the Rapid Phosphatase Test to Dairy Products. HARRY SCHARER, Chemical Laboratory, Dept. of Health, New York City. J. of Milk Techn., *2:* 16–20, 1939.

Phenol standards previously prescribed for the Scharer laboratory test have been replaced by a set of more stable inorganic standards. Instructions for the preparation of these standards are given.

The laboratory test may be increased in its sensitivity by increasing the incubation temperature above 100° F. to 115° F. or by using a two hour incubation period in place of one hour.

Both Scharer's laboratory test or his rapid field test may be applied to milk, cream, chocolate drink, butter, cheese, and ice cream. Instructions for application of the test to these various products are given.

Wherever interfering substances are present, which may give a false positive test, they may be determined by repeating the test substituting buffered water in place of the buffered substrate.

Certain precautions are given. L.H.B.

510. The Pouring Lip and Cap as Sanitary Factors in Bottled Milk. LLOYD ARNOLD, M.D., Dept. of Bacteriology and Public Health, Univ. of Ill., College of Medicine, Chicago, Ill. J. of Milk Techn., *2:* 41–45, 1939.

The pouring lip is a source of contamination, and the development of a glass milk bottle which reduced the area to be covered to a minimum and without drip on pouring is important.

This area should be covered with a sanitary closure to safeguard the bottle content. The plug or disc cap alone, in general use today, does not properly protect the contents. L.H.B.

511. The Present Status of the Paper Milk Container. F. W. TANNER, Dept. of Bacteriology, Univ. of Ill., Urbana, Ill. J. of Milk Techn., *2:* 4–15, 1939.

The paper milk container has certain advantages over glass, particularly from the standpoint of public health. That paper containers when properly made, are almost free of bacteria is proven by examination of thousands of containers of one type. Very few viable bacteria of any kind and no pathogens nor *Escherichia coli* were found. L.H.B.

512. Product-Costs of Milk to Dealers in the Springfield Area, 1935. ALFRED A. BROWN AND J. ELIZABETH DONLEY. Mass. Agr. Exp. Sta. Bull. No. 365, July, 1939.

The factors considered and analyzed in the study are significant of average price, 1935 price level, product-costs to dealers, month to month variation in individual dealer's product-costs, causes of variations in dealers costs F.O.B. the market, cause of variation in percentage of Class II handled by dealers, characteristics of the industry that hinder rapid adjustment in production, alternatives to a market pool, and the relationship between the price for Class I and Class II usage. H.G.L.

513. Draw a Picture for Your Producers. JOSEPH BURNS, Schwartz Milk Co., Two Rivers, Wis. Milk Dealer, *28:* 10, 94, July, 1939.

The author points out the advantages of using the microscope and the sediment test with producers as a means of bringing about the production of good-quality milk. C.J.B.

514. Ropy Chocolate Milk. C. A. TARNUTZER, Bacteriologist, Robert A. Johnston Company, Milwaukee, Wis. Milk Dealer, *28:* 10, 42, 84, July, 1939.

A brief discussion is given of the causes of ropy chocolate milk. C.J.B.

515. Reducing Butterfat Loss. WILLIAM S. JERMAIN, Sparks Dairy, Inc., Buffalo, N. Y. Milk Dealer, *28:* 10, 41, July, 1939.

The installation of a motor-driven agitator in the weight can resulted in a large saving in butterfat loss. Prior to installation of the agitator the average test of composite samples of the milk received from the patrons was about 0.2 per cent higher than the test of the milk processed and the drip test of the milk received. C.J.B.

516. Treatment of Paper Milk Bottles to Delay or Prevent the Oxidized Flavor of Milk. C. D. DAHLE AND D. V. JOSEPHSON, Dairy Dept., Pennsylvania State College. Milk Dealer, *28:* 11, 29, 66–69, Aug., 1939.

Oxidized flavor was delayed or prevented when the milk was stored in paper bottles which had been coated with a mixture of paraffin and oat flour (Avenex). The milk, however, frequently had a flour flavor, the bottles softened and bulged, and the paraffin frequently floated on the milk.

Evidence is presented to show that paper milk bottles made from board which has been sized with oat flour before paraffining aid in preventing or delaying the development of an oxidized flavor in milk. C.J.B.

517. Churned Buttermilk. ANONYMOUS. Milk Dealer, *28:* 11, 32, 83, Aug., 1939.

The Carlson-Frink Company, Denver, Colorado, has opened up an entirely new class of business by selling churned buttermilk. The buttermilk is made by churning sweet cream and sells for 2 cents more per quart than

cultured buttermilk. The new product has not adversely affected the sale of cultured buttermilk. C.J.B.

518. Cutting Milk Delivery Costs. ANONYMOUS. Milk Dealer, *28:* 11, 30–31, 50–54, Aug., 1939.

The cost of operating old trucks *versus* new trucks is shown by comparative data covering 75 delivery trucks operated by milk dealers for home-to-home delivery. The total operating cost for the old trucks was .2232 cent per mile and for the new trucks .1781 cent per mile. This represents a saving of .0451 cent per mile or $45.10 for each 1,000 miles. C.J.B.

519. The Value of the International Association of Milk Dealers from an Educational Point of View. W. H. E. REID, Univ. of Missouri, Columbia. Assoc. Bull., Intern. Assoc. Milk Dealers, *10:* 1, 28, Dec. 20, 1938.

This Association has functioned not only as an aggressive trade organization but as an effective educational institution because of the care with which its technical sectional programs have been built up and conducted. E.F.G.

520. Reduction of Milk Losses in Milk Plants. A. C. DAHLBERG, J. C. HENING AND H. L. DURHAM, New York, Agr. Exp. Sta., Geneva. Assoc. Bull., Intern. Assoc. Milk Dealers, *10:* 1, 11, Dec. 20, 1938.

The daily losses in eight plants in New York State were determined. In one plant it was found that with 3.9 per cent fat in the original milk there was 6.0 per cent fat in the can drainage while the vat rinsings corrected for dilution contained 14.4 per cent fat. Skimming all drainage and rinsings in one plant receiving 96,000 pounds of milk per day resulted in the recovery of 69 pounds of fat in the cream which yielded butter scoring 93. One plant receiving 28,000 pounds of 3.8 per cent milk per day and in which equipment was simple and losses kept at a supposed minimum showed a loss of 3 pounds of fat per day.

The average receipts at the 8 plants was 62,442 pounds of milk containing 2,148 pounds of fat from which 2.5 pounds of fat was lost daily which should have gone into the dump vat. The total losses of fat per plant were 13.6 pounds per day although a portion of this was actually being recovered in various ways.

It is suggested that a supporting bar over the weight can would permit a can to drain while the next one is being dumped and would not materially slow down the receiving process. Or a drainage position ahead of the cold water rinse might be used. Prevention of avoidable losses would also usually solve the stream pollution problem. In this study, extent of dilution of milk in rinsing was measured by a freezing point determination. E.F.G.

521. Grading of Market Milk. B—Reporting Grading Results to the Producer. R. C. DAYTON, Rieck-McJunkin Dairy Co., Pittsburgh, Pa. Assoc. Bull., Intern. Assoc. Milk Dealers, 31st Year, *2:* 53, Jan. 31, 1939.

Among several methods of reporting unsatisfactory quality of milk to the producer a tag in two parts with a check list of the more common defects is recommended. The first part of the tag is tied to the can and the second part kept for future reference. Abnormal conditions should be reported promptly and if possible followed up with a personal letter. E.F.G.

522. Grading of Market Milk. A—Producer's Quality Records. FRANK J. CAPOUCH, Bowman Dairy Co., Chicago, Ill. Assoc. Bull., Intern. Assoc. Milk Dealers, 31st Year, *2:* 51, Jan. 31, 1939.

The importance of fat, lactometer, sediment and bacterial tests as well as flavor and odor in grading of market milk is discussed. E.F.G.

523. Milk Production Trends. JOHN L. WILSON, Bureau of Agr. Ec., U. S. D. A., Washington, D. C. Assoc. Bull., Intern. Assoc. Milk Dealers, 31st Year, *2:* 35, Jan. 31, 1939.

The milk cow is a flexible unit and her production may be increased or decreased as conditions dictate. Total milk production is regulated by two major factors, first, the number of milk cows, and, second, the rate of milk production per cow. During the seven months prior to this time (fall, 1938) normal numbers of dairy cows in relation to population and generous feed supplies have favored heavy production. Heavy feeding will likely continue during the winter. Eighteen cows per 100 are usually discarded per year and replaced by 18 heifers if the number of milk cows is to remain constant. Through decreased culling and increased retention of heifers the stage is set for an increase in numbers of cows beginning one or two years hence in about 1940. This perspective increase might however be interrupted by drought, unfavorable prices or other factors which cannot be accurately forecasted. Also since the cow is a flexible unit her output will be regulated somewhat by the price of the product. E.F.G.

524. Single Service Containers for Milk and Milk Products. J. R. SANBORN AND R. S. BREED, New York State Agr. Exp. Sta., Geneva, N. Y. Cert. Milk, *14:* 154, 7, 1939.

A general discussion of methods for bacteriological control in the manufacture of milk container board is given. The sanitary condition of the foundation board greatly influences the sterility of the paper bottle. A tentative board count of 500 colonies per gram has been set as a reasonable and enforceable standard.

The authors conclude that when food container board is made from

virgin pulp, using pure process water and under sanitary methods of manufacture, a product is produced which is entirely suitable for direct contact with dairy products. W.S.M.

525. Critical Discussion of Some Methods and Standards for Certified Milk. J. H. BROWN, Johns Hopkins Univ., Baltimore, Md. Cert. Milk, *14:* 154, 5, 1939.

Reasons for regarding the supervision of certified milk production as a special problem requiring special methods and standards are given. Special points discussed are: (1) certain features of medical milk commission control, (2) the bacteriological methods and standards for certified milk, and (3) pasteurization of certified milk. W.S.M.

526. An Economic Study of Milk Distribution in Maine Markets. GEORGE F. DOW, Assoc. Economist, Maine Agr. Exp. Sta. Bull. 395, March, 1939.

A detailed analysis of the costs of milk distribution in representative Maine cities and towns obtained by the survey method from 266 milk distributors of which 89 per cent were of the producer-distributor type. It was found that plant costs averaged 36 per cent, container costs 5 per cent, selling and delivery costs 51 per cent, and administration costs 8 per cent. The cost of distribution for the largest raw milk distributors was approximately one cent per quart less than for those with the smallest volume. The pasteurized milk distributors had higher costs than the raw milk distributors, partly because of pasteurization costs and partly because of other costs, such as higher wages. The delivery cost for man and delivery equipment was approximately the same with horses as with motor vehicles for routes up to 15 miles in length. L.M.D.

MISCELLANEOUS

527. Bilateral Variations in the Weight and Composition of the Long Bones of Some Experimental Animals. CHAS. E. WEAKLEY AND R. B. DUSTMAN, W. Va. Agr. Exp. Sta., Morgantown, W. Va. J. Agr. Res., *58:* 9, 711–716, May 1, 1939.

Left and right side bones of rats, chickens, swine and dairy cattle were compared as to green weight and content of moisture, ether extract, ash and organic non-fat. All the animals had been on feeding trials designed to produce differences in bone development and bones of both control and experimental animals were studied. Some of the samples were composites of related bones, *i.e.*, femur, tibia and fibula was one of the composites, seventh and eighth ribs another, etc. No significant differences were found in weight of green bone or in moisture, ash, and organic non-fat of the rat.

Green bone weight was higher for the left side bones of chickens and swine and for the right side bones of dairy heifers than for bones of the opposite sides. Whenever the bones of one side were significantly higher in green weight and moisture than those of the other side they were lower in percentage of ash. The authors conclude that certain species of lower animals may tend toward a dominance of one side over the other with respect to bone development, and that bones from one side are not necessarily identical in composition or other properties with those of the other side, although in general the differences found in their experiments were quite small.

L.M.T.

528. Wage Scales and Working Conditions in Dairy Plants. ANONYMOUS. Milk Dealer, *28:* 11, 41, 61–64, Aug., 1939.

Results of a survey conducted by the Milk Dealer showing methods of payment, especially commission payment plans, methods used in splitting routes, vacations, work-day schedules, etc., in dairies in various parts of the country and including those in small towns. C.J.B.

529. Suggestions for Calculating Cooling Loads for Dairies. C. T. BAKER, Consulting Engineer, Atlanta, Ga. Milk Dealer, *28:* 11, 35, 82, Aug., 1939.

A brief discussion is given of the properties of milk which influence its specific heat and its freezing point. The author also outlines the information which is necessary for calculating the amount of heat to be taken up by the refrigerating machine for any given case. C.J.B.

530. Need for Proper Training of Our Salesmen. T. KLINE HAMILTON, Diamond Milk Products, Inc., Columbus, Ohio. Assoc. Bull., Intern. Assoc. Milk Dealers, 31st Year, 4, 71, Feb. 13, 1939.

This article is a discussion of the use and effectiveness of the I. A. M. D. Balanced Job Program in training route-salesmen. E.F.G.

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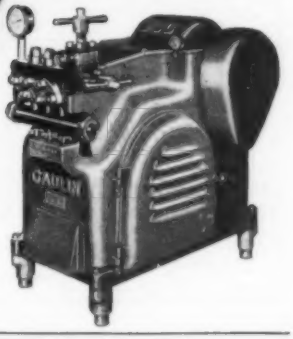

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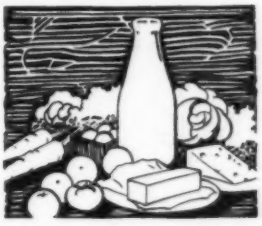

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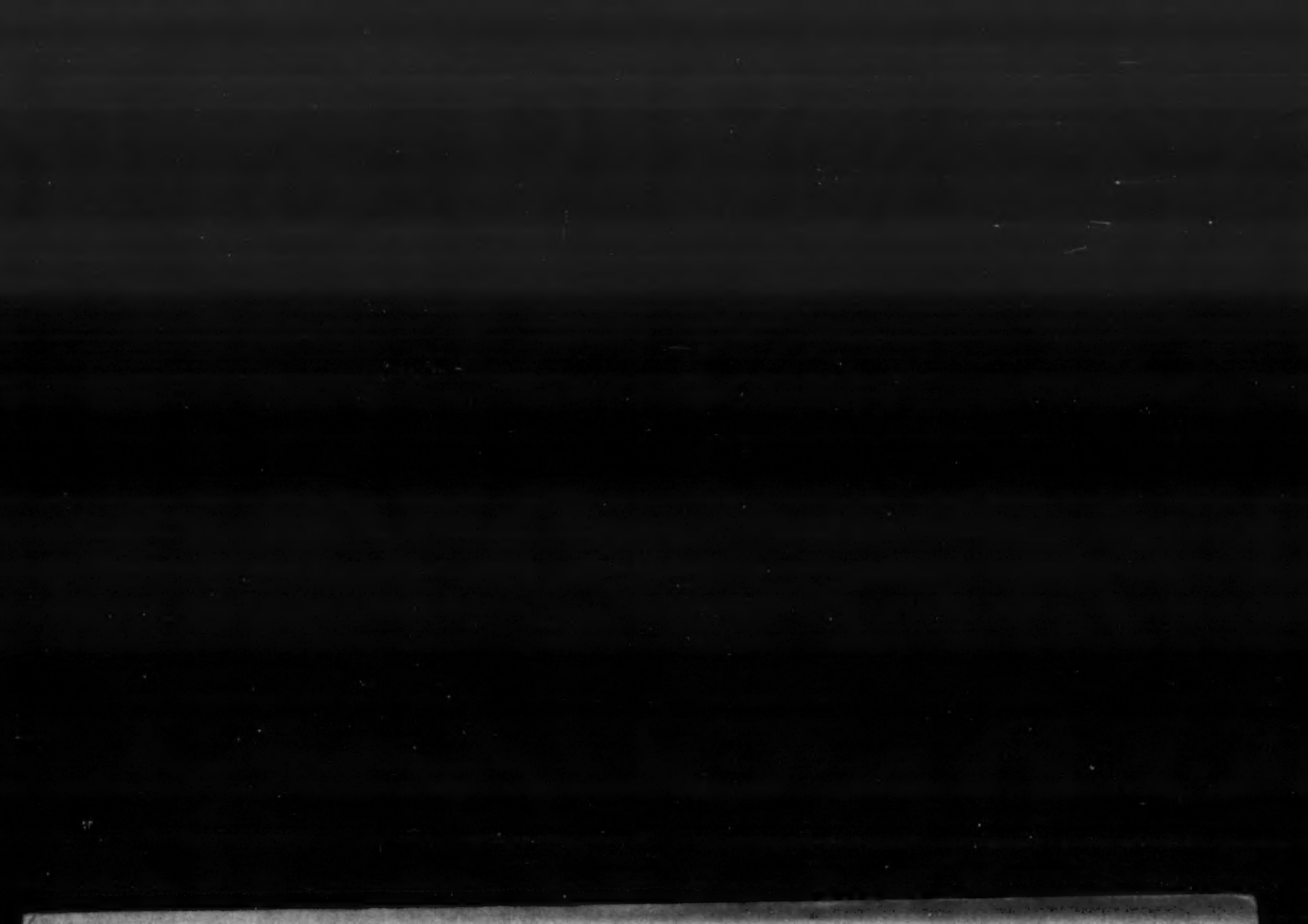
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